SECTION 13300 - INSTRUMENTATION AND CONTROL

City of San Diego, CWP Guidelines

PART 1 -- GENERAL

1.1 WORK OF THIS SECTION

A. The WORK of this Section includes the general specification and requirements for the instrumentation and control WORK under this and other applicable Specifications. The WORK also includes providing instrumentation and all related wiring as shown in these Contract Documents.

B. The CONTRACTOR shall be responsible for the design, procurement, installation, testing, training, and documentation for instrumentation and control systems provided under this Contract. A distributed control system (DCS) is being provided under a separate contract by a control systems provider(CSP) The CONTRACTOR shall be responsible for interfacing with the DCS components, including installing and terminating DCS inputs and outputs (I/O), providing power, and for installing certain CSP-furnished equipment, as defined in Tables 13300-1 through 13300-3 in the Appendix. The CONTRACTOR shall refer to Tables 13300-1 through 13300-3 for additional requirements.

C. Per Section 01300 the CONTRACTOR shall be responsible for the generation of panel wiring diagrams and loop drawings which depict the interconnection between instruments, panels, valve actuators, and MCCs.

$#

NTS: The responsibility for developing loop drawings differs between projects. Ordinarily, the Contractor develops the drawings and forwards them to the CSP for completion of the DCS-related data. On larger projects, the Construction Manager has done this. Alternately, the Design Consultant could do this. Include the following paragraph for CM-provided loops. Modify for Contractor or consultant-provided loop drawings.

#$

D. These drawings shall be forwarded to the CONSTRUCTION MANAGER. The CONSTRUCTION MANAGER will incorporate the CONTRACTOR's data and generate a complete loop drawing for each measuring or control loop. The loop drawing shall include a minimum of 3 sheets as required in paragraph 1.5 B.2.

E. All control system field tests including loop tests, plant commissioning, and plant startup, shall be a responsibility shared by the CONTRACTOR and the CSP. The CSP shall be responsible for providing field and control room personnel to witness the simulation of field inputs associated with the DCS I/O. The CONTRACTOR shall be responsible for providing all personnel and equipment (current drivers, jumpers, read out devices, oscilloscopes, voltage-resistance meters, etc.) required to perform the loop test simulations. All devices used shall be traceable to the

National Institute of Standards and Technology (NIST).

F. The CONTRACTOR shall perform field engineering design as required for mounting and supporting all field mounted components. The CONTRACTOR shall develop any additional schematic and interconnection diagrams which may be required for complete and operable instrumentation.

1.2 RELATED SECTIONS

A. The WORK of the following Sections applies to the WORK of this Section. Other Sections of the Specifications, not referenced below, shall also apply to the extent required for proper performance of this WORK.

1. Section 09800 Protective Coating

2. Division 11 Equipment, as applicable

3. Division 15 Mechanical, as applicable

4. Division 16 Electrical, as applicable

1.3 CODES

A. WORK of this Section shall comply with the current editions of the following codes as adopted by the City of San Diego Municipal Code:

1. Uniform Fire Code

2. National Electrical Code

1.4 SPECIFICATIONS AND STANDARDS

A. Except as otherwise indicated, the current editions of the following apply to the WORK of this Section:

1.	ANSI/ASME B 16.5	Pipe Flanges and Flanged Fittings
2.	API RP-550	Manual on Installation of Refinery Instruments and Control Systems, Part 1 - Process Instrumentation and Control Sections 1 Through 13
3.	ASTM A 105	Specification for Forgings, Carbon Steel for Piping Components
4.	ASTM A 193	Specification for Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service

5.	ASTM A 194	Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service
6.	ASTM A 283	Specification for Low and Intermediate Tensile Strength Carbon Steel Plates, Shapes, and Bars
7.	ISA-RP60.6	Nameplates, Labels, and Tags for Control Centers
8.	ISA-RP7.1	Pneumatic Control Circuit Pressure Test
9.	ISA-RP12.6	Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations
10.	ISA-S5.1	Instrument Symbols and Identification
11.	ISA-S5.4	Instrument Loop Diagrams
12.	ISA-S12.4	Instrument Purging for Reduction of Hazardous Area Classification
13.	ISA-S20	Specification Forms for Process Measurement and Control Instrumentation; Primary Elements and Control Valves
14.	ANSI - B16.1	Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800
15.	ANSI/AWWA C207	Steel Pipe Flanges for Waterworks Service - Sizes 4 In Through 144 In.
16.	ANSI/AWWA C701	Cold-Water Meters - Turbine Type for Customer Service
17.	ANSI/AWWA C702	Cold-Water Meters - Compound Type
18.	AWWA C704	Cold-Water Meters - Propeller Type for Main Line Applications
19.	ASTM A 126	Specification for Gray Iron Castings for Valves, Flanges and Pipe Fittings
20.	ASTM B 61	Specification for Steam or Valve Bronze Castings
21.	ANSI/AWWA	Ductile-Iron and Gray-Iron Fittings, 3-In Through C110/A21.10 48-In for Water and Other Liquids
22.	ASME REPORT	Fluid Meters, Sixth Edition, 1971

1.5 SHOP DRAWINGS AND SAMPLES

A. Presubmittal Conference:

1. The CONTRACTOR shall arrange and conduct a Presubmittal Conference within [60] days after Notice to Proceed. The purpose of the Presubmittal Conference is to review and approve the manner in which the CONTRACTOR intends to carry out his responsibilities for shop drawing submittal on the WORK to be provided under this Section. The CONTRACTOR and the CONSTRUCTION MANAGER shall attend. Both the CONTRACTOR and the CONSTRUCTION MANAGER may invite additional parties at their discretion.

2. The CONTRACTOR shall allot [two, 8]-hour days for the Conference.

3. The CONTRACTOR shall prepare the following for discussion at the Conference:

   a. List of equipment and materials for the instrumentation systems, including proposed manufacturer names and model numbers.

   b. List of proposed clarifications to the indicated requirements plus a brief written explanation of each exception. Review and acceptance of proposed clarifications will be according to Section 01600.

   c. One complete example of each type of submittal proposed.

   d. A flow chart showing the steps the CONTRACTOR will take in preparing and coordinating each submittal to the CONSTRUCTION MANAGER.

   e. A bar chart type schedule for the WORK provided under this Section, covering the time period beginning with the conference and ending after startup and training. Dates for the beginning and ending of submittal preparation, submittal review, design, fabrication, programming, factory testing, delivery to the site, installation, field testing, and training shall be scheduled. The schedule shall be subdivided into major items or groups of items which are on the same schedule.

4. The CONTRACTOR shall furnish [3] copies of all the items above to the CONSTRUCTION MANAGER.

5. The CONTRACTOR shall take formal minutes of the Conference, including all events, questions, and resolutions. Prior to adjournment, all parties must concur with the accuracy of the minutes and sign accordingly.

B. **Shop Drawings:**

1. General:

a. Preparation of shop drawings shall not commence until adjournment of the Presubmittal Conference.

b. In the Contract Documents, all systems, meters, instruments, and other elements are represented by symbology derived from the latest version of ANSI/ISA S5.1. The nomenclature and numbers indicated herein shall be used exclusively in all shop drawings. No manufacturer's standard symbology or nomenclature shall replace those indicated in the Contract Documents.

c. During the period of shop drawing preparation, the CONTRACTOR shall maintain a direct, informal liaison with the CONSTRUCTION MANAGER for exchange of technical information. As a result of the exchange, certain minor refinements and revisions to the indicated systems may be authorized informally by the CONSTRUCTION MANAGER but these shall not alter the WORK or cause increase or decrease in the Contract Price. During informal exchanges, no statement by the CONSTRUCTION MANAGER shall be construed as approval of any component or method or exception to or variation from these Contract Documents.

d. All shop drawings shall include the letterhead or title block of the CONTRACTOR. The title block shall include, as a minimum, the CONTRACTOR registered business name and address, project name, drawing name, revision level, and personnel responsible for the content of the drawing.

e. Shop drawing copies shall be submitted as standard size 3-ring, loose-leaf, vinyl plastic binders suitable for bookshelf storage. Maximum binder size shall be 2 inches.

f. A complete index shall be placed at the front of each binder.

g. A separate technical brochure or bulletin shall be included for each instrument, meter system, and other element. The brochures shall be indexed by systems or loops. If, within a single system or loop, a single item is employed more than once, one brochure may cover all identical uses of that item in the system. Each brochure shall include a list of tag numbers to which it applies. System groups shall be separated by labeled tags.

h. Shop drawings shall be submitted as a single package at one time within 90 days of the commencement data stated in the Notice to Proceed.

i. All shop drawings shall be produced in using Microstation CAD formats. Each shop drawing submittal shall include the requisite number of hard copies and one (1) Microstation electronic copy. Upon completion of this project, the Contractor shall submit four (4) electronic copies of all current shop drawings.

$#

NTS: Include the following paragraph for Contractor-provided loops. Delete for CM or consultant-provided loop drawings.

#$

2. Loop diagrams in accordance with Section 01300 conforming to ISA 5.4 to verify the DCS interfaces with all instrumentation and devices being provided or installed under the project. The loop diagrams shall also define all interfaces with equipment provided by area Contractors. The following three-sheet format is required:

   a. Sheet 1: A device schedule developed from an electronic spreadsheet or database file, which will be submitted with the loop diagrams. The table will show the following.

      (1) Device tag number, with Prefix, Unit Process, ISA Tag Prefix, Tag No. (a three or four-digit number based on the loop number) and Tag suffix
      (2) Equipment Service
      (3) Device Type
      (4) Location
      (5) Device Manufacturer
      (6) Model No.
      (7) Spec. No.
      (8) Area Contractor (if applicable
      (9) Submittal No.
      (10) Calibrated Range/Remarks
      (11) Data Sheet No.
      (12) I/O Signal type (AI, AO, DI, or DO)
      (13) Signal Level
      (14) Device Range (full available instrument range)
      (15) Engineering Units
      (16) Process Set Point
      (17) Loop Diagram No., reflecting the field instrument tag number.
      (18) Loop Drawing File Name
      (19) Interconnect Drawing File Name

   b. Sheet 2: Provide loop drawing meeting the Requirements of ANSI/ISA S5.4, except that intermediate terminal junction boxes may be omitted and be shown on Page 3 for clarity. Butt splices and wire nuts shall be shown on as-builts, with the corresponding termination housing (JB, LB, etc. shown on Sheet 3).

   c. Sheet 3: Provide point-to-point conduit and wiring diagram, showing instrument, wire and cable numbers, intermediate terminal junction boxes, and PCM terminations. Wire identification numbers will reflect the field instrument tag number, and not the DCS I/O number.

   d. DCS I/O tag numbers will generally reflect the device tag number. Each I/O tag number will be unique. The tag prefix will be based on ISA-5.4, with the following

additional special acronyms:

Acronym	Signal Use
YL	Ready Signals/ Motor Run
ZL	In Computer status
ZSO	Device Open
ZSC	Device Closed
YL	Motor Run
HS	In Computer Switch

3. Technical brochures, bulletins and data sheets containing:

   a. Fully completed ISA S20 data sheets

   b. Component functional descriptions

   c. Locations or assembly at which component is to be installed

   d. Materials of a component's parts which will be in contact with process fluids or gases

4. Shop Drawings of differential pressure producing flow tubes and elements, showing the device's proportions and performance. The CONTRACTOR shall furnish a certified curve from the manufacturer showing flow versus differential pressure for each flow metering device furnished. Where applicable, the following data shall be furnished for each device:

   a. Coefficient values and tolerances

   b. Effects of upstream configuration

   c. Headloss as a function of the velocity head expended

   d. Test results from a recognized hydraulic laboratory showing that the discharge coefficient is within 0.75 percent of standard for each meter. Documentation tabulating tests of at least [30] different meters of the same type which show compliance with the two standard deviation tests in ASME "Fluid Meters," Sixth Edition, will be an acceptable alternative.

5. Schematic and wiring diagrams for control circuits shall be submitted in two stages. Initially, schematic control diagrams shall show complete details on the circuit

interrelationships of all devices within and outside each Control Panel. Subsequent to acceptance of all schematic control diagrams, by the CONSTRUCTION MANAGER, piping and wiring diagrams shall be submitted. The diagrams shall consist of component layout drawings to scale, showing numbered terminals on components together with the unique number of the wire to be connected to each terminal. Piping and wiring diagrams shall show terminal assignments from all primary measurement devices, such as flow meters, and to all final control devices, such as pumps, valves, chemical feeders and local control panels. Wiring diagrams shall include MCC Panel, circuit, and breaker number for each power feed

6. Assembly and construction drawings for each alarm annunciator, local indicating panel and for other special enclosed assemblies for field installation. These drawings shall include dimensions, identification of all components, surface preparation and finish data, and nameplates. These drawings also shall include enough other details, including prototype photographs, to define exactly the style and overall appearance of the assembly; a finish treatment sample shall be included.

7. Installation, mounting, and anchoring details for all components and assemblies to be field-mounted, including conduit connection or entry details.

8. Complete control panel layouts, all drawn to a 1-1/2 inch=1 foot scale showing:

   a. Physical arrangements which define and quantify the physical groupings of annunciators, handstations, recorders, indicators, pilot lights and all other instrumentation devices associated with control panel sections, auxiliary panels, subpanels and racks.

   b. All cutout locations fully dimensioned. All outside panel dimensions shall be shown.

   c. Locations of back-of-panel stiffeners.

   d. Terminal point locations for all panel and back-of-panel piping and wiring connections. Terminations shall be coded with identifiers for wiring and piping connections for all electric, hydraulic and pneumatic terminations.

   e. Nameplate engraving list.

   f. A complete and detailed bill of material list shall be submitted for each field mounted device or assembly as well as cabinet assemblies and subassemblies. Bills of material shall include all items within an enclosure. An incomplete submittal shall be rejected and no further evaluation performed until a complete and detailed bill of material is submitted

1.6 OWNER'S MANUAL

A. Information included in the OWNER'S MANUAL shall comply with the requirements of Section

01300 with the following exceptions:

1. Two copies of the OWNER'S MANUAL shall be submitted after acceptance of all submittals under Paragraph 1.6. One set will be returned to the CONTRACTOR with comments.

2. Final copies of the OWNER'S MANUAL, after revision, shall be submitted to the CONSTRUCTION MANAGER 15 days prior to startup.

B. The following shall be included in the OWNER'S MANUAL in accordance with Section 01300:

1. Installation, connection, operating, troubleshooting, maintenance, and overhaul instructions from the manufacturer.
2. Exploded or details views of all instruments, assemblies, and accessory components.

3. Parts lists and ordering instructions.

4. Wiring diagrams.

5. A list of spare parts for 1 year operation recommended by the manufacturers of all analog equipment.

1.7 AS-BUILT DRAWINGS

A. As-built drawings shall be prepared in accordance with Section 01300 with the following exceptions and changes:

1. The CONTRACTOR shall keep current an approved set of complete loop diagrams and schematic diagrams which shall include all field and panel wiring, all piping and tubing runs, all routing, all mounting details, all point-to-point diagrams with cable, wire, tube and termination numbers. These drawings shall include all instruments and all instrument elements for the complete instrument loop as provided under Divisions 11, 13, 14, 15, and 16 of this Contract.

2. One set of original drawings and two copies of each as-built drawing under this Section shall be submitted to the CONSTRUCTION MANAGER after completion of field checkout but before placing the systems in service for the OWNER'S use.

3. Drawings shall also be submitted in electronic format (Microstation)

1.8 SERVICES OF MANUFACTURER

A. **Calibration, Testing and Startup**: A technical service representative of the manufacturer shall visit the site and perform the following on all flow meters and analyzers.

1. Inspection, checking and calibrating the equipment.

2. Startup and field testing for proper operation.

3. Performing field adjustments to ensure that installation and operation comply with the Specifications.

B. **Instruction of OWNER'S Personnel**: The manufacturer's technical service representative shall instruct the OWNER'S personnel as indicated in Paragraph 3.4.

1.9 SPECIAL GUARANTEE

A. The CONTRACTOR shall guarantee the WORK of this section for two years following final acceptance of the WORK. In making any warranty repairs, the CONTRACTOR shall utilize technical service personnel designated by the manufacturer of the failed device. Repairs shall be completed within 5 days after written notification by the OWNER.

1.10 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. **Delivery of Materials**: Products delivered to the site for incorporation into the WORK of this Section shall be delivered in original, unbroken packages, containers, or bundles bearing the name of the manufacturer.

B. **Storage:** Products shall be carefully stored in a manner that will prevent damage and in an area that is protected from the elements.

1.11 ENVIRONMENTAL CONDITIONS

A. General: All instrumentation and control system components and associated wiring shall be suitable for use in a treatment facility environment where there may be high energy AC fields, DC control pulses, and varying ground potentials between transducers and system components. The system design shall be adequate to provide proper protection against interferences from all such possible situations.

B. Field Situated Equipment: The instrumentation and control system shall be installed on a wastewater treatment plant site. All devices shall be designed to exist in environments rated (G2)(G3)(GX) per ISA S71.04. The system design shall be adequate to provide proper protection the environment typically associated with these facilities. As a minimum, the instrumentation and control systems shall be designed and constructed for satisfactory operation and low maintenance requirements under the following environmental conditions:

1. Temperature Range: 0 through 50 degrees C (32 through 122 degrees F)

2. Thermal Shock: 0.55 degrees C per minute (1.0 degrees F per minute)

3. Relative Humidity: 20 through 95 percent (non-condensing)

C. **Control Room Situated Equipment:** Control rooms shall be air conditioned to achieve the

environmental noted in item B herein. (No positive control of relative humidity is provided.) In the event of a failure of the air conditioning system, all components of the instrumentation and control system shall be rated to operate in an environment where the ambient temperature is 15 through 35 degrees C (59 through 95 degrees F) and the relative humidity is 20 to 95 percent (non-condensing).

D. **Noise Tolerance:** The instrumentation and control system components shall not exceed a db level of 55 when monitored 3-feet away from the devices. If upon testing it is found that this limit is exceeded at the option of the CONSTRUCTION MANAGER and at no additional cost to the OWNER, devices shall be replaced in order to achieve a maximum level of 55 db or sound absorption materials shall be added.

1.12 CABLE NUMBERING

A. The first two characters denote the facility or area number.
B. The second group of characters identifies the device being served (field device, not
C. The third section uses one of the four suffixes in the table below. Where multiple circuits of the same type are routed to the same endpoint, the suffix will be P1, P2, as required.

D. At each device or termination point, the circuit identification number is appended with the individual wire number. For Direct-Current (DC) circuits only, wire polarity is shown in parentheses as (+) or (-).

E. Spaces are not allowed, and letters are not case-sensitive, and written in upper case.

SUFFIX	CIRCUIT TYPE	EXAMPLE
(A)	24 v dc analog (4-20 mA)	01FIT022(A)-1(+)
(C)	120 volt AC control	05P320(C)-2
(D)	24v dc digital status or control	55LSH201(D)-1(+)
(P)	Power (120 volt, 480 v, 5 kv, 15 kv, etc.)	01MCC6101(P)-2

PART 2 -- PRODUCTS

2.1 GENERAL

A. All meters, all instruments, and all other components shall be of the most recent field-proven models marketed by their manufacturers at the time of submittal of the shop drawings unless otherwise indicated.

B. Panel mounted instruments shall have matching style and general appearance. Instruments performing similar functions shall be of the same type, model, or class, and shall be of one

manufacturer.

C. Outdoor instrumentation shall be suitable for operation in the ambient conditions at the equipment installation locations. Heating, cooling, and dehumidifying devices shall be incorporated with the outdoor instrumentation in order to maintain it within its rated environmental operating ranges. The CONTRACTOR shall provide all power wiring for these devices. Outdoor enclosures suitable for the environment shall be provided.

D. Mercury switches and components containing liquid mercury shall not be used.

E. All instrumentation in hazardous areas shall be intrinsically safe or be approved for use in the particular hazardous classification in which it is to be installed.

F. Analog measurements and control signals shall be electrical and shall vary in direct linear proportion to the measured variable, except as indicated. Electrical signals outside control board(s) shall be 4 to 20 milliamperes DC except as noted. Signals within enclosures shall be 1-5 volts DC unless otherwise specified. Dropping resistors shall be installed at all field side terminations in the control panels to ensure loop integrity.

G. The accuracy of each instrumentation system or loop shall be expressed as a probable maximum error; this shall be the square-root of the sum of the squares of certified "accuracies" of the designated components in each system, expressed as a percentage of the actual span or value of the measured variable. Each individual instrument shall have a minimum accuracy of ± 0.5 percent of full scale and a minimum repeatability of ± 0.25 percent of full scale unless otherwise indicated. Instruments which do not conform to or improve upon these criteria are not acceptable.

H. Control panels shall be provided with redundant power supplies which are configured in a fault-tolerant manner to prevent interruption of service upon failure and interruption of service necessitated by the replacement of a power supply. All power supplies shall have an excess rated capacity of 40 percent. The failure of a power supply shall be annunciated locally and shall generate an alarm to the DCS.

I. Each control loop shall be individually fused.

2.2 CONTROL PANELS

$#

NTS: It is MWWD's intent to minimize the use of local and vendor control panels. The DCS shall be used as the primary control system. Small PLCs may be used as relay replacements if the number of relays exceeds 10 to 15. See Design Guidelines, Chapter D6 for guidance on use of PLCs. Generally, PLCs are used only in pumping stations and when supplied by a vendor as a part of a packaged system. The designer should be cautious about using redundant PLCs: generally, using the DCS for control is more reliable and easier to manage than a redundant PLC configuration. Communication between control panel PLCs and the DCS shall be via RS-232 MODBUS RTU protocol (with the PLC acting as a MODBUS slave) or Ethernet (for larger PLCs). See Design Guidelines for additional data link requirements.

#$

A. General: Control panels, including those furnished by equipment manufacturers, shall be provided according to the following requirements.

1. Where indicated, control panels shall be provided with all required taps, fittings, rotameters, regulation and alarm interlocks to enable the implementation of a purge system which is in conformance with ISA-S12.4 Type Z requirements. Dimensions shall be in accordance with manufacturer's requirements. Elevations and horizontal spacing shall be subject to CONSTRUCTION MANAGER'S approval.

2. All control panels which require NEMA 3 or 4 ratings will be provided with window kits to preserve the panels integrity and enable operations ready access to information.
3. Panels shall be fabricated, piped and wired by fully qualified workmen who are properly trained, experienced and supervised.

$#

NTS: List all panels, their locations/area classification and their specific requirements under paragraph 2.2A4.

#$

4. Control panels shall satisfy the following requirements:

Panel No.	Location	Area Classification	Specification Section to be Provided Under	Electrical Drawing #

B. **Materials**:

1. Panel section faces shall be #10 gage minimum thickness steel for free standing panels and #14 gage minimum thickness steel for smaller panels. All materials shall be selected for levelness and smoothness.

2. Relay rack high density type panels shall utilize standard relay racks with 14 gage steel frame and supports.

3. Structural Shapes and Strap Steel: ASTM A 283.

4. Bolting Material: Commercial quality carbon steel bolts, nuts and washers, all ½-inch diameter with UNC threads. Carriage bolts shall be used for attaching end plates. All other bolts shall be hex head machine bolts. All nuts shall be hot pressed hex, American Standard, heavy. Standard wrought washers shall be used for foundation bolts and

attachments to building structures. All other bolted joints shall have S.A.E. standard lock washers.

C. **Fabrication**:

1. End plates, top plates and top closure panels shall be furnished when required. End plates, top plates and top closure panels shall be removable with countersunk bolts to match panels. Top closure panels shall be furnished in lengths which match the widths of standard panels, except that one top closure panel may extend across two 4-feet 6-inches wide or five 2-feet 0-inches wide standard panels. The vertical joints of these panels shall align with the vertical joints of the standard panels.

2. End closure or rear closure doors shall be provided. Such doors shall be flush fitting and gasketed and be of the hinged lift-off type with lockable door handles. A common key shall be provided for all doors on one panel assembly. Where removable access panels are indicated, they shall be furnished with dished handle fasteners. Screw driver 1/4 turn type fasteners are not acceptable.

   a. The flanged edges of all panels shall be straight and smooth. Corners shall be welded and ground smooth.

   b. The face of the panel shall be true and level after flanging.

   c. All panel cut-outs and holes may be cut or drilled by any standard method that will not cause deformation. Burrs shall be ground smooth.

   d. Adjacent panels shall be assembled with faces flush. Gaps or cracks shall not be visible from the front of the assembled instrument board.

   e. Stiffeners shall be welded to the back of panels, as required to prevent panel deformation due to the weight of front of panel mounted instruments.

   f. Panels shall be self-supporting as defined below.

D. **Framework and Supports:**

1. The rear of each panel section shall have a steel framework for supporting conduit, tubing, wireways, switches, air piping and all instrument accessory items such as relay or terminal enclosures, transducers, pressure switches, valves and air relays. The main frame work shall be constructed of standard structural shapes. Special shapes such as "Unistrut" may be used for secondary supports. Framework must not interfere with instrument connections or access needed for maintenance or adjustments.

2. Steel framework shall extend 2-feet 8-inches back of the panel face unless otherwise required. Where indicated, individual adjustable leg supports shall be provided at the back of the framework so that the entire panel shall be self-supporting.

E. **Finish:**

1. Preparation: The front and rear face of the panel, both sides and the edges of all flanges, and the periphery of all openings shall be prepared as follows.

   a. All high spots, burrs, and rough spots shall be ground smooth.

   b. The surfaces shall be sanded or sandblasted to a smooth, clean bright finish.

   c. All traces of oil shall be removed with a solvent.

2. Finishing:

   a. A 3-mils dry coat of Amercoat 185 or equal primer shall be applied over the entire panel surface immediately after solvent cleaning.

   b. Wet sand, dry, then quick glaze spot putty on the front of the panel only. Dry, then wet sand again and dry.

   c. Apply a second 3-mils dry coat of alkyd enamel primer to the front of the panel.

   d. Wet sand to smooth clear finish, then dry.

   e. At least two 3-mil dry coats of air-dry, satin finish, alkyd enamel shall be applied over the entire surface. Color to be as selected by CONSTRUCTION MANAGER.

   f. The CONTRACTOR shall furnish two 1-pint containers of the enamel to the CONSTRUCTION MANAGER.

3. Instrument Finishing:

   a. The final coats applied to painted surface of instrument cases, doors, or bezels which are visible from the front of panels shall be manufacturer's standard unless otherwise indicated. Black japan or "crinkle" finishes on instrument cases are not acceptable

F. **Mounting of Instruments:**

1. The CONTRACTOR shall provide cut-outs, and shall mount all instrument items indicated to be panel mounted, including any instruments indicated to be furnished by other manufacturers.

2. The CONTRACTOR shall also mount, behind the panels, other instrument accessory items as indicated.

3. Rear of panel mounted equipment shall be installed with due regard to commissioning adjustments, servicing requirements and cover removal.

4. Wiring shall be kept clear of spare space to give maximum space for future additions.

G. **Piping Requirements for Control Panels**:

1. General:

a. The CONTRACTOR shall provide terminal connections near the top, rear of the panel for all tubing and piping which connect to instruments, valves, air supply and other pressure leads external to the panel. Terminal connections for tubing shall be bulkhead tube unions. Those for pipe shall be threaded couplings, plugged for shipping purposes.

b. Each terminal connection shall have an engraved metal or plastic plate with a terminal and instrument tag number affixed nearby.

c. The CONTRACTOR shall provide the air supply pressure reducing station, all instrument and supply piping and all pneumatic tubing or piping to terminal connections and between instruments located within the confines of the panel and supporting framework.

2. Air Supply Piping:

a. The CONTRACTOR shall provide air supply piping from a point near the top of the panel framework to the inlet side of the pressure reducing station, or alternately to the inlet side of individual filter regulators.

b. Piping, fittings and valves downstream of the filters at the air supply reducing station shall be brass or copper. Headers may be extruded aluminum if the tube wall section is thick enough to accept threaded connections.

c. The low pressure instrument air supply header shall extend from the down stream side of the main pressure reducing valves across the length of panel which includes air users. Where the header must be broken for shipping purposes, brass unions shall be provided at the panel section junctions.

d. A separate air supply take-off consisting of a 1/4-inch brass connection braced into the air header (if brass or copper) shall be furnished for each instrument requiring an air supply. An additional 10 percent of the take-offs shall also be provided. Take-offs for 3/4-inch size headers may be made by using 3/4-inch by 3/4-inch by 1/4-inch reducing tees.

e. Each take-off shall be fitted with a 1/4-inch brass diaphragm of needle type shut-off valve. Provide circular type handle with tag number shown thereon.

f. The dead end of the air header opposite the supply end shall be fitted with a plugged

½-inch brass gate valve.

g. The connection from the shut-off valves air head to the instruments shall be by means of 1/4-inch or 3/8-inch O.D. tubing as required

H. **Electrical Requirements for Control Panels**:

1. The CONTRACTOR shall provide all wiring, conduit, wireways, and switches required to make instruments and other panel electrical devices operational.

2. Conduit, wireways, junction boxes and fittings shall be installed for all signal wire, all thermocouple and resistance thermometer lead wire including those between temperature sensors and temperature indicators.

3. Each terminal connection shall have a plastic plate with a terminal and instrument tag number. All wiring shall be identified with stamped tubular wire markers.

4. Freestanding panels shall be provided with switched 100-watt incandescent back-of-panel lights which are powered from a source independent from that which powers the panel devices. One light shall be provided for every 4 feet of panel width and shall be mounted inside in the top of the back-of-panel area.

5. Freestanding panels shall be provided with a 15-amp, 120 volt service outlet circuit within the back-of-panel area which are powered from a source independent from that which powers the panel devices. The circuit shall be provided with one 3-wire, 120-volt, 15-ampere, duplex receptacle for every 4 feet of panel width spaced evenly along the back-of-panel area. As a minimum, 2 duplex outlets shall be provided for each panel.

6. Smaller panels shall be sized to adequately dissipate heat generated by equipment mounted in or on the panel.

7. Where smaller panels are mounted outside or in unshaded areas, they shall be provided with thermostatically controlled heaters capable of maintaining inside temperatures above 40 degrees F.

8. Smaller panels shall be provided with a hand-switch controlled 100-watt incandescent light and a breaker protected 120-volt, 15-amp duplex receptacle.

9. Wiring Methods: Wiring methods and materials for all panels shall be in accordance with the NEC requirements for General Purpose unless otherwise indicated. Opening wiring in close cabinet type panels is allowed when indicated.

10. Construction:

a. Wire for 115-volt circuits shall be No. 14 AWG stranded with Type THWN or THHN insulation. All terminals for external wiring connections shall be suitable for

No. 12 AWG wire.

b. Flexible conduit is not acceptable.

c. Conduit fittings shall be cast fittings.

d. Soldered or pressure crimped wire splicing in conduits shall be acceptable.

e. For case grounding, panels shall be provided with a 1/4-inch by 1-inch copper ground buss completed with solderless connector for one No. 4 AWG bare stranded copper cable. The CONTRACTOR shall connect the copper cable to a system ground loop.

f. Single case annunciator units with no remote logic which are installed at the top of a panel may be considered as being a terminal box when top of panel wire entry is indicated. If bottom of panel entry is indicated, terminal box shall be provided at the bottom of the panel and wired to the annunciator. Terminals shall be identified with plastic marker strips.

g. Terminal boxes for incoming and outgoing signal leads shall be located at the top or bottom of the panel as indicated or as otherwise required.

11. Power Supply Wiring:

a. Unless otherwise indicated, all instruments, all alarm systems, and all motor controls shall operate on 24 VDC circuits.

b. The CONTRACTOR shall furnish terminal box connections for the main power supply entry as indicated.

c. Power supply switches for alarm units shall be three pole type, arranged to open both the power and alarm circuits. Each annunciator shall be equipped with a separate switch.

d. Instruments located on a single panel section which serve one process unit may be connected to a common branch power circuit. The number of branch circuits shall be such that no circuit load exceeds 10 amps. Different panel sections and instruments serving different process units shall not use common branch circuits. A 15-amp, two-pole circuit breaker shall be provided in each branch circuit. When instruments do not come equipped with integral fuses, the panel fabricator shall furnish and install fuses as required for the protection of individual instrument against fault currents. Fuses shall be mounted on the back of the panel, in a fuseholder, with each fuse identified by a service name tag.

e. Each potentiometer type instrument, electronic transducer, controller or analyzer shall have an individual disconnect switch. Disconnect switches shall have metal or plastic tags listing the associated instrument tag numbers. Individual plug and cord

set power supply connections may be used without switches when indicated.

f. Where alarm units are single unit types, one switch may be used to disconnect not more than six alarm units located on the same or adjacent panels.

12. Alarm Wiring: The CONTRACTOR shall provide all alarms including light cabinets, audible signal units, test and acknowledge switches and remote logic units as indicated. Interconnecting wiring to panel mounted initiating devices shall also be provided. Wiring from external initiating devices shall be provided by the CONTRACTOR. Where plug and cord sets are provided for component interconnection, the CONTRACTOR shall harness and support the cables in a neat and orderly fashion. Where separate wire is required, the CONTRACTOR shall install 16 AWG with THWN or THHN insulation between all components.

13. Signal Wiring:

a. Computer and Non-Computer Use:
Signal wire shall be twisted shielded pair or triads in conduit or troughs. Cable shall be constructed of No. 16 AWG copper signal wires with THWN or THHN insulation. Color code for instrument signal wiring shall be:

(1) Positive - Black (+)

(2) Signal Ground Negative - White (-)

(3) Equipment Ground - Green
(4) Ungrounded - Red

(5) Energized by voltage sound external to panel - Yellow
(6) DC circuit - Blue

b. Multiconductor cables where indicated shall consist of No. 16 AWG copper signal wires twisted in pairs, with 600 volt fault insulation. A copper drain wire shall be provided for the bundle with a wrap of aluminum polyester shield. The overall bundle jacket shall be PVC.

c. Multi-conductor cables, wireways and conduit shall provide for 10 percent allocation of spare, unused signal wires in addition to the indicated requirements.

14. Thermocouple Wiring:

a. The CONTRACTOR shall provide metal wire troughs, pullboxes, and thin walled conduit for duplex thermocouple lead wire in a manner which will facilitate field installation of lead wire without splices or terminal connections. The CONTRACTOR shall also provide the lead wire connections between multipoint temperature sensors and temperature indicators when indicated. When a

thermocouple junction box is indicated, it shall be located with the approval of the CONSTRUCTION MANAGER. The panel manufacturer shall install conduit and troughs and lead wires between the junction box and the instruments. Terminal material shall be compatible with extension wire used.

b. Thermocouple lead wire shall be No. 16 AWG with high temperature PVC insulation on each wire and PVC jacket overall, and shall conform to the latest ISA Specification for standard grade.

c. Conduit for thermocouple lead wire shall be in accordance with the following:

CONDUIT SIZE	½"	3/4"	1"	1½"	2"
NO. OF DUPLEX LEADS	1	4	6	16	26

d. Where the number of duplex lead wires exceeds 26, the wires shall be installed in rectangular ducts filled to not more than 40 percent capacity.

e. All thermocouple wireways and main conduits shall be sized to allow for 10% spare thermocouple leads.

f. Each signal, control, alarm, and indicating circuit conductor shall be designated by a single unique number which shall be shown on shop drawings. These numbers shall be marked on all conductors at every terminal using white numbered wire markers which shall be plastic-coated cloth, or shall be permanently marked heat-shrink plastic.

15. Terminal Blocks: Terminal blocks shall be molded plastic with barriers and box lug terminals, and shall be rated 15 amperes at 600-volts. White marking strips, fastened securely to the molded sections, shall be provided and wire numbers or circuit identifications shall be marked thereon with permanent marking fluid.

I. **Color Conventions:** Lens covers for indicating lights on all panels will be colored as follows:

1. Red-ON when;

- Motor not running (STOPPED)
- Valve CLOSED (not fully opened)
- Device not energized.
- Circuit breaker OPENED

2. Green-ON when;

- Motor running in forward direction (fast speed for multi-speed motors).
- Valve OPEN (not fully closed)
- Device energized.

C Circuit breaker CLOSED

3. White-ON when;

C Power available
C System in AUTOMATIC mode.
CMonitoring taking place.

4. Amber-ON when;

C Malfunction trip.
C Equipment locked out.
C Alarm condition

J. **Nameplates:** Nameplates shall be provided for instruments, function titles for each group of instruments, and other components mounted on the front panel(s) as indicated. A nameplate shall be provided for each signal transducer, signal converter, signal isolator, and electronic trip mounted inside the panel(s). Nameplates shall be descriptive to define the function and system of such element. These nameplates shall be of the same material as those on the front of the panel(s). Adhesives shall be used for attaching nameplates. Nameplates shall be fabricated from black face white-center laminated engraving plastic. Painted surfaces shall be prepared to allow permanent bonding of adhesives. Colors, lettering, styles, abbreviations and sizes shall be in conformance with ISA-RP60.6 with an intended viewing distance of 3 feet to 6 feet.

K. **Factory Inspection:**

1. Panels shall be inspected for compliance with requirements at the factory before shipment to the site. The CONTRACTOR shall notify the CONSTRUCTION MANAGER 2 weeks in advance of the testing date. A representative of the CONSTRUCTION MANAGER will visit the factory to make the inspection.

2. CONTRACTOR shall perform the following tests prior to arrival of the CONSTRUCTION MANAGER:

a. All air lines adequately tested for leaks.

b. All alarm circuits rung out to determine their operability.

c. Electrical circuits checked for continuity and where applicable, operability.

d. Nameplates checked for correct spelling and correct size of letters.

e. Other test required to place the panel in an operating condition.

3. It shall be the responsibility of the CONTRACTOR to furnish all necessary testing devices and sufficient manpower to perform the tests required by the CONSTRUCTION MANAGER to determine conformance to the requirement of the Contract documents.

4. If the above tests have not been performed prior to the arrival of the CONSTRUCTION MANAGER, the CONTRACTOR shall reimburse the OWNER for the cost of the extra time required for the inspector's services and travel expenses

L. **Shipment:**

1. Panels shall be crated for shipment using a heavy framework and skids. Panel sections shall be cushioned to protect the finish of the instruments and panel during shipment. Instruments which are shipped with the panel shall have suitable shipping stops and cushioning material installed to protect instrument parts from mechanical shock damage during shipment. Each panel crate shall be provided with removable lifting lugs to facilitate handling

2.3 GENERAL INSTRUMENTATION ENCLOSURE COMPONENTS

A. **Signal Isolators, Converters, and Power Supplies:** Signal isolators shall be provided in each measurement and control loop, wherever required, to match adjacent component impedances, or where feedback paths may be generated or to maintain loop integrity when the removal of a component of a loop is required. Signal converters shall be provided where required to resolve any signal incompatibilities. Signal power supplies shall be provided to supply sufficient power to each loop component.

B. **General Purpose Relays:** General purpose relays in the Control Panels shall be plug-in type with contacts rated [10] amperes at 120 volts ac; quantity and type of contacts shall be as indicated. Each relay shall be enclosed in a clear plastic heat and shock resistant dust cover. Sockets for relays shall have screw type terminals.

C. **Time Delay Relays:** Time delay relays shall be electronic on-delay or off-delay type with contacts rated 10-amperes at 120-volts AC. Units shall include adjustable dials with graduated scales covering the indicated time range.

D. **Slave Relays:** Slave relays shall be provided when the number or type of contacts indicated exceed the contact capacity of the indicated relays and timers.

E. **Circuit Breakers:** Circuit breakers shall be single pole, 120-volt, 15 ampere rating or as required to protect wiring and equipment. Circuit breakers shall be mounted inside the panels as shown.

$#

NTS: Specific nameplates should be defined in a schedule on the drawings.

#$

$#

NTS: The following technical specifications define the minimum criteria for various field instrumentation devices. The designer shall require the use of "smart" transmitter when those devices are available and are intended to communicate with the DCS.

#$

2.4 FLOW MEASURING SYSTEMS

A. **Magnetic Flow Measuring Systems:** Magnetic flowmeter systems shall be of the low frequency electromagnetic induction type and produce a DC pulsed signal directly proportional to and linear with the liquid flowrate. Complete zero stability shall be an inherent characteristic of the flowmeter system. Each magnetic flow metering system shall include a metering tube, signal cable, transmitter and flowmeter grounding rings.

1. The metering tube shall have the following attributes:

   a. constructed of 304 or 316 stainless steel with flanged connections
   b. utilize a minimum of 2 bullet-nosed, self-cleaning electrodes
   c. liner in conformance with the manufacturer's recommendation for the meters intended service
   d. electrodes constructed of materials which are in conformance with the manufacturer's recommendation for the meters intended service
   e. meter housing rated for NEMA 6 submergence conditions
   f. meter coating consisting of epoxy painted finish
   g. two grounding rings which are in conformance with the manufacturer's bore and material recommendation for the meters intended service. Grounding rings shall be designed to protect and shield from process abrasion the liners edge interface at the meters end:

2. The microprocessor-based signal converter/transmitter shall have the following attributes:

   a. utilize DC pulse technique to drive flux-producing coils
   b. convert DC pulse signal from the tube to a standardized 4-20 mA signal into a minimum of 700 ohms
   c. 6 digit LCD display for flow rate, percent of span, and totalizer
   d. an operator interface consisting of keypads which respond to English text entry
   e. integral zero return to provide a consistent zero output signal in response to an external dry contact closure
   f. integral low flow cutoff and zero return

g. automatic range change

h. capable of measuring flow in both directions

i. programmable parameters including meter size, full scale Q, magnetic field frequency, primarily constant, time constant

j. data retention for a minimum of 5 years without auxiliary power (main or battery)

k. self diagnostics and automatic data checking

l. protected terminals and fuses in a separate compartment which isolates field connection from electronics

m. utilize "Smart" technology which employs a hand-held configuration terminal and outputs a digital flow signal superimposed on 4-20 mA signal and complies to protocol which is ungradable to SP 50.

n. produces a scalable frequency output, 0 to 100 Hz, transistor switch closure up to 5.75 W externally powered, 5, to 24 VDC

o. can tolerate ambient temperature operating limits of -20 to 140 degrees F (-29 to 60 degrees C)

3. Each flow metering system shall be hydraulically calibrated at a facility which is traceable to the National Institute of Standards and Technology. The calibrations procedure shall conform to the requirements of MIL-STD-45662A. A real-time computer generated printout of the actual calibration data indicating apparent and actual flows at 20%, 40%, 60%, 80% and 100% of the calibrated range shall be submitted to the Construction Manager at least thirty (30) days prior to shipment of the meters to the project site. The flow metering system shall conform to the following technical specifications: Time constant = 0.5 to 1000 seconds; galvanic or optic isolation: Accuracy: 0.25 of flow rate from 10 to 100% full scale for velocities over 3 FPS: Repeatability: 0.25% full Scale: Power consumption: 30 watts or less: Power Requirements: 120 VAC, ± 10% (24 VDC)

4. The following magnetic flow measuring systems shall be provided:

Tag No.	Size	Range	Liner Material	Electrode Material	NEMA Rating (Body/Transmitter)

a. **Propeller Flow Measuring Systems:** The flowmeter shall be designed to operate

continuously at any flow rate within the rated range. Meter accuracy shall be ± 2 percent of rate at any flow from the minimum rating to 150 percent of maximum rating. The meter shall be wet flow calibrated against a primary standard accurate to ± 0.25 percent. Two copies of the calibrations taken at or near minimum flow rating, at mid-range and at the highest flow rate within the range attainable by the test facility shall be furnished to the Construction Manager. Meter-mounted indicators, totalizer, and transmitters, or any combination thereof, shall be of the same manufacture as the propeller meters. The meterhead shall be mounted on a flanged connection for ease of removal from the pipe, for inspection or service. The meterhead shall consist of a cast iron or steel cover plate bronze or cast iron gear box, stainless steel, Delrin, hard rubber or ceramic wetted working parts and acceptable injection molded engineered grade thermoplastic propeller. The drive mechanism shall be by means of stainless steel worm, worm gear shafting with O-ring packing or a ring angle or ceramic radial sleeve magnetic drive, as shown in Schedule. The meter shall be equipped with [a 6-digit straight reading totalizer with center sweep test hand, protected by an all metal or sealed, injection molded plastic register box and cover assembly, with locking hasp.] [a 6-digit straight reading totalizer, test hand, and instantaneous rate of flow indicator, protected by an all metal, or sealed, injection molded plastic register box and cover assembly, with locking hasp.] [a 6-digit straight reading totalizer-transmitter with center sweep test hand,] and a [4-20 mA dc] and [scaled pulse output,] protected by an all metal, or sealed, injection molded plastic register box and cover assembly, with locking hasp. Use of external converters shall not be acceptable. Zero and span shall be field adjustable and shall not cause loss of local totalization while in operation. Meters, 2-inch to 4-inch in size, shall be furnished with straightening vanes in cast iron tubes lined with stainless steel, or fusion epoxy coating. The ends shall be flanged to ANSI standards. Meters 6-inch through 36-inch in size, shall be furnished with either saddles and straightening vanes, or with flanged tubes with integral vanes. Vanes shall be fabricated of carbon steel with AWWA Class D flanges. The tubes and straightening vanes shall be lined and coated with a 7-mil minimum coating of epoxy polyamide or equal with the outside of the tube further protected by the manufacturer's standard protective coating. Meters, 42-inch to 72-inch in size, shall be furnished with saddles and straightening vanes.

The following propeller meters shall be provided:

Tag No.	Service	Size Inches	Flow Rate gpm/mgd	Pressure Rating	Process Connec-tion	Direct or Mag Drive	NEMA Rating

b. **Ultrasonic Flow Measuring System (Factory Mounted):** Two sensors shall be

factory welded to a straight pipe on opposite sides of the pipe, installed to ensure that acoustic pulses are transmitted diagonally upstream and downstream across the centerline of the pipe. Probes shall be wetted, removable under pressure and flow conditions and shall be rated for 250 psig working line pressure. Meter shall be designed to operate on 120V ac supply with a power consumption of not more than 30 watts for indoor mounting and 250 watts for outdoor mounting with heater. The probes shall be fabricated of non-corrosive material and shall be equipped with an armored triaxial cable. The equipment manufacturer shall recommend and select the signal and frequency to be utilized for the measurement to ensure process pipeline and shall comply to Section 02650 for welded steel cement mortar-lined installation requirements. The electronic unit recommended by the manufacturer to measure the flow of water in the pipe shall be housed in a NEMA 4X housing designed for wall-mounting. The electronic unit shall utilize the output of the velocity sensing probes to measure fluid velocity in each pipe and shall be factory wired, solid state. The electronic unit shall include an integral totalizer display and a rate display. An attached programming unit shall include a signal strength indication display for use during calibration of the meter unit. The transmitter unit shall produce an isolated 4 to 20 mAdc output signal capable of driving a load impedance of 600 ohms at 24 VDC, and a scaled pulse output signal proportional to the flow rate.

The following flow measuring systems shall be provided:

Tag No.	Service	Pipe Size (inches)	Line Pressure (psi)	Flow Range (gpm)

c. **Ultrasonic Flow Measuring System (Field Mounted):** Meters shall be directional and utilize ultrasonic velocity measurement principles. Field-mounted ultrasonic flow meters shall consist of transducers mounted in bosses welded directly to metal pipes, or transducers mounted to gasketed saddles strapped to concrete or plastic pipe. The meters shall be suitable for measuring [raw sewage] [treated sewage effluent] [RAS/WAS] [raw water] [drinking water] with an accuracy of ±2 percent at flows above one foot per second, and a range of 10 to 1, or 25 to 1 at higher velocities. Two sensors shall be permanently mounted to a straight pipe provided by the CONTRACTOR, with weldments or Type 316 stainless steel straps on opposite sides of the pipe, such that the acoustic pulses pass diagonally upstream and downstream across the centerline of the pipe. The probes shall be wetted and removable under pressure and flow conditions. The meter shall be designed to operate on 120 VAC supply with a power consumption of not more than 30 watts indoor and 250 watts outdoor with heater. The probes shall be fabricated of non-corrosive material and shall be equipped with an armored triaxial cable for electric transmission. The equipment manufacturer shall select the signal and frequency to be utilized for the measurement to assure proper ultrasonic

transmission. The electronic unit shall utilize information from the velocity sensing probes to accurately measure fluid velocity in each pipe. All wiring within the electronic unit shall be factory pre-wired. The transmitter unit shall produce a 4 to 20 mA-dc signal, and a scaled pulse output signal, if totalization is required, proportional to the flow rate. A local flow indicator, scaled in the specified flow range, shall be provided and installed in an accessible location for easy reading.

The following field mounted ultrasonic measuring systems shall be provided:

Tag No	Service	Pipe Size Inches	Flow Range gpm	Line Pressure psi	Pipe Material	NEMA Rating

d. **Wafer Type Magnetic Flow Measuring Systems:** Magnetic flowmeter systems shall be of the low frequency electromagnetic induction type and produce a DC pulsed signal directly proportional to and linear with the liquid flow rate. Compete zero stability shall be an inherent characteristic of the flowmeter system. Each magnetic flow metering system shall include a metering tube, signal cable, transmitter and flowmeter grounding rings. The metering tube shall be constructed of 304 or 316 stainless steel wafer type, have at least two (2) diametrically opposed bullet-nosed self cleaning electrodes, a liner material recommended by the manufacturer for the meters intended service as described in these documents, a meter housing rated for NEMA 6 submergence conditions, and a meter coating consisting of epoxy painted finish. The system shall utilize tow (2) grounding rings for a system ground. all grounding shall conform to the manufacturers requirements. The signal converter/transmitter shall use a DC pulse technique to drive flux-producing coils and convert the DC pulse signal form the tube to a standardized 4-20 mA signal. The signal converter/transmitter shall have a six (6) digit back lit indicator, be housed in a remotely mounted NEMA 4X enclosure, have integral zero return to provide a constant zero output signal in response to an external dry contact closure, an integral calibration self-test feature to verify proper operation of the electronics, high and low alarms and an automatic zero adjustment. Each flow metering system shall be hydraulically calibrated at the facility which is traceable to the National Bureau of Standards. The calibration procedure shall conform to the requirements of MIL-STD-45662A. A real-time computer generated printout of the actual calibration data indicating apparent and actual flows at 20%, 40%, 60%, 80%, and 100% of the calibrated range shall be submitted to the CONSTRUCTION MANAGER at least thirty (30) days prior to shipment of the meters to the project site. The flow metering system shall conform to the following technical specifications: **Output:** 4-20 MA into 600 ohms minimum; Time Constant = 0.5 to 100 seconds; galvanic or optic isolation: Accuracy: 0.25% of flow rate from 10 to 100% full scale for velocities over 3 FPS: Repeatability: 0.25% Full Scale: Environmental Limits: T

= - 25 to + 160F: Power Consumption: 30 watts or less.

The following wafer type magnetic flow measuring systems shall be provided:

Tag No.	Size	Range	Liner Material	Electrode Material	NEMA Rating (Body/Transmitter)
					/
					/

e. **Paddle Wheel Flow Measuring Systems:** Paddle wheel insertion meters shall be devices that can be built into pipelines of any material and up to 96 inches in diameter. They shall be designed for easy insertion and withdrawal under pressure, of materials suitable for the intended service. The meter stem shall contain an electronic pickup, sensing the passage of each rotor blade. A pulsed output shall produce a repetition rate directly related to flow velocity. The meter shall be capable of registering flow with an accuracy of ±2 percent over a 10 to 1 range, with a negligible pressure loss. The meter inserts shall be made of Type 316 stainless steel or of plastic material suitable for the intended service. The shaft material shall be stainless steel, titanium, or Hastelloy. The paddle wheels shall be of Type 316 stainless steel or suitable plastic. The meter inserts shall be mounted securely through a screwed, flanged, welded, or socket-welded tee connection or fitting, for precise positioning in the pipeline. The fittings shall be of the same material as the pipeline and, unless otherwise called out, the inserts shall be easily retractable and replaceable under line pressure through a gate or ball valve with a gland and retaining cable or chain. The mounting hardware or probe shall include a clear indicating device to correctly position the meter insert in the pipeline. The meter shall be furnished with a local flow indicator for mounting on the pipeline, the insert, or the wall, with all necessary connections and supports. The indicator shall read in [cubic feet per minute] [cubic feet per hour] [gallons per minute], and it shall be enclosed in a corrosion-resistant and weatherproof housing. [The meter shall generate a 4-20 mA output into 600 ohms.]

The following paddle wheel flow measuring systems shall be provided:

Tag No.	Service	Flow Range cfm-gpm	Pipe Size Inches	Inlet Pressure in. W.C.	Service Temp deg. F.	Pipeline Material	NEMA Rating

f. **Vortex-Shedding Flow Measuring Systems:** The meters shall be of the enhanced vortex-shedding type, utilizing the Karmon Vortex-shedding phenomenon, with either thermal, pressure, or ultrasonic sensing. The sensor shall not be wetted

by the liquid. The meters shall be suitable for indoor or outdoor installation and they shall have an accuracy of ± 1 percent over a range of 10 to 1. The meter body shall be of Type 316 stainless steel with a Type 316 stainless steel flow element. The body shall fit between a pair of standard pipe flanges and it shall be of weather-proof construction. The direct-mounted flow indicator/transmitter shall be encased in a rotatable, weather- [and explosion-proof] aluminum housing and it shall produce a 4 to 20 mA-dc signal output proportional to the flow rate. The transmitter shall be suitable for operation on 120-volt, ac, single-phase, 60 Hz supply.

The following vortex-shedding flow measuring systems shall be provided:

Tag No	Service	Pipe Size Inches	Flow Range gpm	Line Pressure psi	Operating Temp deg. F	NEMA Rating

g. **Rotameter Flow Measuring Systems:** Unless otherwise shown, all rotameters in chemical solutions lines and where shown shall have vertical bottom inlets and top outlets with ANSI 150-lb flanged ends, for vertical mounting. Meters in air, and pump seal flushing lines shall be of the modified rotameter design with screwed ends, spring-loaded pistons, and union bodies for mounting in any position. All meters shall be rated for a minimum working pressure of 150 psi. All flanged rotameters for chemical solutions and other service, where shown, shall be calibrated in gallons per minute. The meters shall have Hastelloy C floats, 10-inch long scales, and a range of 10:1 with an accuracy of ± 2 percent. the scales shall be suitable for the capacity ranges shown. The following body materials shall be used for the rotameters:

1. Activated carbon solution - all Type 316 stainless steel construction with magnetically actuated float and scale.

2. Other chemicals - Type 316 stainless steel ends with heavy borosilicate glass tubes and packing glands, or other best suitable material.

All rotameters with NPT screwed ends for water, air, and fuel gas service shall be calibrated in gallons per minute or cubic feet per minute. The bodies shall have union ends for ease of maintenance, polysulphone tubes, aluminum or brass end fittings, Type 316 stainless steel internal parts and scales suitable for the capacity range shown in the schedule above. The meters shall have an accuracy of not less than ± 5 percent over the capacity range shown.

The following rotameter flow measuring systems shall be provided:

Tag No.	Service	Flow Range gpm	Pipe Size Inches	Line Pressure psi	Flanged or Screwed

h. **Mechanical Batch Flow Measuring Systems:** The meters shall be designed to operate intermittently at maximum flow rate within the rated range, and with an accuracy of ± 1 - ½ percent within that range. The meters shall be furnished complete with control registers, shut-off valves, and linkage to measure a pre-set amount of water. The meter shall be of the positive displacement type using discs or pistons, measuring chambers and sealed gears. The body shall be of bronze, with screwed or flanged ends, flanged body for servicing, stainless steel trim, hard rubber or other suitable plastic disc or piston. The flexible spindle between gear and register shall have a stuffing box with minimum friction, or the register shall be hermetically sealed with a magnetic drive. The meter shall be suitable for a working pressure of not less than 125 psi, unless otherwise specified. The valve shall automatically stop the flow through the meter when a pre-wet quantity of liquid has been delivered. The meter shall have a resettable 5-digit display to measure batches up to [5,000] gallons. The automatic stop shall be performed mechanically by a valve linked to the register. The valve shall have a 2-stage closure, which closes partially as the end of the delivery nears to prevent shock pressure when the valve close completely. The meter, register, valve, and linkage shall be a completely assembled unit, not requiring any electrical wiring or pneumatic lines.

The following mechanical batch flow measuring systems shall be provided and installed:

Tag No.	Service	Flow Range gpm	Pipe Size Inches	Pressure Rating psi	Process Connection

i. Electronic Batch Flow Measuring Systems: The meters shall be designed to operate intermittently at maximum flow rate within the rated range, and with an accuracy of ±1-1/2 percent within that range. The meters shall be furnished complete with control registers, electrically operated valves, and switches to measure a pre-set amount of water into chemical mixing tanks. The meters shall be of the positive displacement type or turbine type, using discs or pistons, or rotors, measuring chambers, and sealed gears. The body shall be of bronze, with screwed or flanged ends, flanged body for servicing, stainless steel trim, hard rubber or plastic disc or piston, or plastic rotor, and oil enclosed gear. The turbine-type meters shall have

straightening vanes in the inlet. The drive shall be hermetically sealed, of the magnetic type. Pressure rating shall be 125 psi operating pressure, unless otherwise specified. The automatic reset control unit shall be enclosed in a sturdy cast aluminum, brass, or stainless steel housing, mounted directly on the meter body. It shall have a large, calibrated dial with a 6-digit totalizer and an automatic reset motor, suitable for 115-volt ac power supply. Internal wiring shall terminate at an easily accessible connector strip. The preset quantity shall be adjustable from one percent to 100 percent of total dial capacity. The dial shall be calibrated in gallons. The control unit shall be operated in conjunction with a motor-operated ball valve or a solenoid valve. After a pre-determined quantity of water is measured, a cam shall close an electric circuit and close the valve in the line.

The following electric batch flow measuring systems shall be provided:

Tag No.	Service	Flow Range gpm	Pipe Size Inches	Pressure Rating psi	Process Connection

j. **Displacement Flow Measuring Systems:** The flowmeters shall be designed to operate continuously at any flow rate within the rated range, and with an accuracy of ±1-1/2 percent within that range. The meters shall be of the positive displacement type using discs or pistons, measuring chambers and sealed gears. The body shall be of bronze, with screwed or flanged ends, flanged body for servicing, stainless steel trim, hard rubber or other suitable plastic disc or piston, and oil enclosed gear. The register shall be hermetically sealed with a magnetic drive and it shall indicate and totalize in gallons or cubic feet. Minimum pressure rating shall be 125 psi operating pressure, unless otherwise specified.

The following displacement flow measuring systems shall be provided:

Tag No.	Service	Flow Range gpm	Pipe Size Inches	Pressure Rating psi	Process Connection

k. **Venturi Flow Measuring Systems:** The meter shall be of the pressure differential-producing type utilizing pure static pressures sensed at the inlet and at the throat, without the use of devices which amplify differential through change in direction of flow at the cross-sections where inlet and/or throat static pressure is sensed. The inlet section which incorporates the high pressure tap shall be a

cylindrical section of the same diameter as the pipe. The throat section shall be cylindrical for a minimum length of ½ of the throat diameter. The low pressure tap shall be installed in the throat section. The metering element shall be free of debris-collecting cavities or annular chambers and shall have a single pressure connection at the inlet and one at the throat. The venturi body shall be of cast iron per ASTM A 126, Grade B, with bronze throat per ASTM B 61, or of carbon steel with stainless steel trim. All internal, ferrous surfaces shall be coated in accordance with the requirements of Section 09800 - Protective Coating. The tubes shall have plain ends for welding, grooved ends for mechanical type couplings, or flanged ends per ANSI/AWWA C110/A21.10, or AWWA C207.

Where shown, meters shall be of the short pattern Venturi tube, plastic-insert type, with necessary pressure connections and transmitting equipment as specified below. Flow tubes shall have glass fiber polyester plastic outlet, inlet cone, and holding flange. Capacity, size, and location of flow tubes shall be as shown in the schedule.

The following venturi flow measuring elements shall be provided:

Tag No.	Service	Size (in)	Flow Range gpm	Differ-ential (in W.C.)	Ends or Insert	Material of Tube

l. **Orifice Plate Flow Measuring Systems:** Each orifice meter shall consist of an orifice plate, placed between a pair of ANSI 125-lb cast iron, or 150-lb steel flanges as shown. The flanges shall have ½-inch pressure taps and stainless steel tubing to flow indicator or transmitter. Unless otherwise specified, all orifice plates shall be made of annealed Type 316 stainless steel, with a minimum thickness of 1/8-inch, as recommended by the manufacturer. The surface finish shall be within 15-20 micro inches roughness and the concentricity within 3 percent of the inside diameter of the meter tube. Tolerances for the bore shall comply with AGA and ASME specifications. The seals shall be of Teflon with stainless steel retainer rings.

The following orifice plate flow measuring systems shall be provided:

Tag No	Service	Pipe Size Inches	Max Flow gpm or cfm	Diff Inches W.C.	Line Pressure psi	NEMA Rating

m. **Pitot Tube Flow Measuring Systems:** The averaging pitot tube shall consist of a perforated metering tube to be inserted into the main pipe, the necessary mounting and isolating hardware, two connecting tubes, and a wall-or pipe-mounted flow indicator and/or transmitter. The metering tube shall be installed in such a way, that it can be withdrawn from the main pipe under pressure, without interruption of the service. The meter shall be capable of registering the flow with an accuracy of ±2 percent over a range of 4:1, with a pressure loss not to exceed 3 percent of the output differential. The metering tube shall be fabricated of heavy gage Type 316 stainless steel, for insertion through the centerline of the main pipe. It shall have a series of inlet and outlet ports and two passages connecting to the flow readout device. The tube shall terminate at the top in a stainless steel bar stock tee, for connection to the instrument tubes. The metering tube shall be mounted through a flanged or threaded connection, welded to the main pipe, or through a saddle clamp for non-metallic and cast iron pipe. The mounting hardware shall include a gate or ball valve, a packing gland, a restraining chain, and all required fittings. Where necessary, a vent or settling chamber shall be added for trouble-free operation. The mounting hardware shall be of Type 316 stainless steel, except for the welded connection to the main pipe, which shall be made of a 3000-lb carbon steel half-coupling or a 300-lb carbon steel welding fitting and flange. The entire assembly shall be rigidly constructed. The metering tube shall be connected to its instrumentation by means of 2 Type 316 stainless steel tubes with balancing and isolating valves and union fittings of a size recommended by the manufacturer. The tubes shall be as short as possible and firmly supported.

The following pitot tube flow measuring systems shall be provided:

Tag No.	Service	Flow Range	Pipe Size Inches	Inlet Pressure in. W.C. - psi	Pressure Differences in. W.C. - psi

n. **Differential Pressure Flow Transmitters:** Electronic gauge pressure transmitters shall be of the differential pressure type and consist of a capsule assembly, bottom works, weatherproof and bugproof atmospheric vent assembly, drain plug, cover, flange, process connector and connection, Teflon gaskets, amplifier unit, integral indicator, terminal box with cover, block an bleed valves, and conduit connections. Pressure applied to the transmitter shall be transmitted by a sealed fill fluid to both sides of a sensing diaphragm. The sensing diaphragm and the sensor body shall function as the moving and fixed electrodes of a differential capacitor respectively. As the applied pressure causes the diaphragm to move, the capacitance of the cell shall change. The transmitter enclosure (topworks) shall be rotatable to facilitate access to the electronics with an over-rotation stop to prevent damage to sensor wires. The amplifier unit shall convert the change in capacitance to a 4-20 mA DC

signal, 2 wire type, with an allowable loop load of no less than 575 ohms. Transmitter design shall incorporate voltage surge and RFI protection. Static pressure rating shall be a minimum of 500 psig. The maximum over-range pressure limit shall be a minimum of 150 percent of the maximum range. Span shall be adjustable over a minimum of a 5:1 range. External adjustments shall include zero and span. Output signal damping shall be provided as an internal adjustment. Square root extraction circuitry shall be provided which can easily be added or removed from the transmitter. All equipment shall be suitable for an ambient operating range of minus 40 degree F to plus 212 degrees F. All wetted parts shall be constructed of 316 stainless steel. All block and bleed valves shall be constructed of 316 stainless steel. Bolts from process covers and process connectors shall be of the same material as that specified for the process covers. The topworks shall be constructed of low copper die-cast aluminum and finished with epoxy paint. The integral indicator shall have a linear scale and be calibrated in process units. Power supply shall be 24 VDC. Accuracy, including linearity and repeatability, shall be a ± 0.2 percent of span. Hysteresis shall be limited to 0.05 percent of span. Drift, over a six month period shall not exceed 0.1 percent of reference minus 0.5 percent of maximum span per 100 degrees F.

The following electronic differential pressure transmitters shall be provided:

Tag No.	Range	Body/Bolt Material	Fill Fluid	Process Connection	NEMA Rating

o. **Differential Pressure Flow Rate Indicators:** Flow rate indicators shall have a six inch, 270 degree dial with two scales, one differential pressure and one flow rate graduated to match the characteristics at the differential producer. The indicator shall be actuated by 316 stainless steel bellows. The housing material shall be 316 stainless steel with a safe working pressure of 500 psi minimum. Accuracy shall be ± ½ percent of full scale. Each indicator shall be furnished with a 316 stainless steel three valve manifold.

The following flow rate indicators shall be provided:

Tag No.	Range	Process Connection

p. **Propeller Flow Measuring Systems (Open-Flow):** Each propeller meter shall have a 4-pole magnetic-type drive preventing the process fluid from contacting any

gears, overrun bearings, shafts, etc., within the meter. The rotation of the propeller shall be transmitted from the magnetic drive to the register and transmitter (where required) by means of a flexible connecting shaft. Flowmeters shall be designed to operate continuously at flow rates within the rated range. Meter accuracy shall be ± 2 percent of rate at flow from the minimum rating to 150 percent of maximum rating. The meter shall be wet-flow calibrated against a primary standard accurate to ± 0.25 percent at the following ratings: minimum flow; midrange; and at the maximum. Meter-mounted indicators, totalizers, and transmitters shall be manufactured by the same manufacturer as the propeller meters.

Meters shall be of the open-flow type, designed for headwall mounting and to measure flows in submerged influent conduits. Meter shall consist of: injection molded thermoplastic propellers; bronze or cast iron gear boxes; bronze, epoxy-coated steel or stainless steel drop pipes; and stainless steel, Delrin, hard rubber, or ceramic in contact with fluids. The drive mechanism shall include stainless steel worm gear and shafting or ceramic radial-sleeve magnetic drive with water-lubricated ceramic sleeve bearings and oil-filled sealed gear box. Shafts shall be stainless steel. The meter shall be equipped with [a 6-digit direct reading totalizer with center sweep test hand, protected by an all-metal or injection-molded plastic register box and cover assembly with locking hasp] [a 6-digit direct reading totalizer, test hand and instantaneous flow rate of flow indicator]. The unit shall be protected by an all-metal or injection-molded plastic, register box and cover assembly with locking hasp.] [a 6-digit direct reading totalizer-transmitter (with test hand), with 4-20 mA-dc and scaled-pulse output protected by an all-metal or injection-molded plastic, register box and cover assembly with locking hasp.] External converters are not acceptable. Zero and span shall be field-adjustable and designed not to cause loss of totalization while in operation. Meters shall include straightening vanes designed to be mounted in the influent pipe immediately preceding the propeller and located in accordance with the manufacturer's installation instructions.

Meters 10 inches to 30 inches in size shall include bronze or cast iron rabbit-ear mounting brackets with the lower bracket designed to serve as a guide for positioning the meter on the lower-bracket locking pin when submerged. Meters 36 inches to 72 inches in size shall include bronze or cast iron scabbard mounting brackets or rabbit-ear mounting brackets. Where indicated, meters shall include revolving mounting frame and brackets designed for installation and removal of the meter when submerged in flowing fluids. Brackets shall permit removal of the meter by lifting the meter 6 inches, rotating it 180 degrees, and then extracting it vertically in guide rails. Mounting frames shall be fabricated from stainless steel, or hot-dipped galvanized carbon steel. Submerged supports and anchor bolts shall comply with Section 05500.

The following open-flow propeller flow measuring systems shall be provided:

Tag No.	Service	Pipe Size	Range	Riser Length	Type of Brackets	Drive Type	Output

q. **Turbine Gas Flow Measuring Systems:** Meters shall be of the turbine type with flanged cast aluminum body, built-in straightening vanes, molded plastic turbine rotors, and magnetic drives, and designed for vertical or horizontal installation. Meters shall be suitable for totalizing the flow of gas in cubic feet units at an accuracy of ± 1 percent over a range of 10 to 1, at 0.25 psig pressure. Meters shall be designed for a differential pressure drop of 4.25 inches W.C., based on 0.6 specific gravity and 0.25 psig inlet pressure. Meters shall be cast aluminum or cast steel bodies with 150-lb flanged ends, a flanged, interchangeable pre-calibrated measuring cartridge, integral plastic straightening vanes, and plastic rotors with magnetic drives. Meters shall include precision bearings fabricated of stainless steel with external fittings designed to permit lubrication while the meter is in operation. Parts exposed to gas shall be fabricated of corrosion-resistant materials. Meters shall include direct mounted totalizers, reading in cubic feet. Meters shall be equipped for direct-mounting of mechanical, electro-mechanical, or electronic read-out and transmitting devices.

The following turbine gas flow measuring systems shall be provided:

Tag No.	Service	Pipe Size	Inlet Pressure	Range	Output

r. **Rotary Gas Flow Measuring Systems:** The meters shall be of the rotary, positive displacement lobe or vane type, designed for vertical or horizontal installation and with moving parts enclosed in a cast aluminum housing. Meter shall be designed for measuring and totalizing gas flow in cubic feet units at an accuracy of ± 0.5 percent from 10 to 100 percent of capacity, and with a maximum pressure loss of 0.8-inch W.C. at 100 percent of rated capacity. The meters shall include magnetic coupling or sealed stainless steel bearings designed to transmit the rotation of the rotor to the instrument drive mechanism. The drive mechanism shall be isolated from the rotor and the gas flow. The rotor shall be dynamically balanced and fabricated of corrosion-resistant material. The body shall be of cast iron coated in accordance with Section 09800, or cast aluminum, hard-coat anodized internally and shall include 125-lb flanges complying with ANSI B16.1. Bearings and shafts exposed to the gas stream shall be stainless steel. Bearings shall comply with Section 11000. The meters shall be suitable for outdoor installation. The bearings shall be shielded with self-lubricating timing gear or shall be splash-lubricated and

monitored by oil level gauge.

The following rotary gas flow measuring systems shall be provided:

Tag No.	Service	Pipe Size	Inlet Pressure	Range	Output

s. **Diaphragm Gas Flow Measuring Systems:** The meters shall be of the diaphragm displacement type designed with moving parts enclosed in an aluminum housing. The meters shall be suitable for measuring and totalizing the flow of gas in cubic feet units at an accuracy of ± 1 percent from 10 to 100 percent of capacity. Moving parts of the diaphragm displacement type meter shall be housed in a flanged die-cast aluminum alloy body. Valves, linkages, and the diaphragm assembly shall be mounted on a common plate for easy removal. Bearings shall be of the low-friction type and the design shall include a bolted access cover to permit adjustment. The totalizer assembly shall be mounted outside of the meter body, and shall be protected by a hinged cover. Both inlet and outlet connections shall be threaded. The meters shall be designed for outdoor installation [and for minimum pressure loss].

The following diaphragm gas flow measuring systems shall be provided:

Tag No.	Service	Pipe Size	Inlet Pressure	Range	Output

t. **Parshall Flume Flow Measuring Systems:** Fiberglass reinforced plastic liner shall comply with Section 06610. Full-length, molded, fiberglass-reinforced polyester Parshall Flume liners shall be installed in the flume channels for measurement of [raw sewage plant influent] [and/or] [plant effluent] flow. Flumes shall be provided with [integral, molded side cavity and bubbler system] [Type 304 stainless steel mounting bracket and ultrasonic level sensing system] designed to measure the flow [and a factory installed gauge calibrated in tenths of feet mounted on the sidewall]. The flume insert shall be a full-length, molded, fiberglass-reinforced polyester liner fabricated in one piece from polyester resin and reinforced with glass mat. Not less than 30 percent (by weight) of the flume insert shall be reinforcement. The thickness of the walls shall not be less than 1/4-in. There shall be a sufficient number of locking clips or flanges integral with the liner to ensure secure anchorage and proper alignment. Integral stiffeners shall be designed to withstand shipping and installation. Temporary spreaders may be placed across the top of the flume to

prevent damage. The flume shall be designed for trouble-free operation to produce metering heads to within 2 percent of its published rating curve. The flume shall include integrally molded stilling wells and stainless steel brackets for mounting of instruments.

Tag No.	Service	Throat Width	Channel Width	Flow Range				Output
				Initial		Ultimate		

u. **Mass Flow Gas Measuring Systems:** The mass flow meters shall be designed to operate continuously on the thermal dispersion principle, at flow rates within rated range. The meters shall be suitable for service with digester gas from sewage treatment plants. Digester gas is a moisture-saturated, corrosive gas composed of methane, carbon dioxide, nitrogen, hydrogen sulfide, and particulates. The mass flow meter shall be of the single insertion probe type. The insertion probe shall have flanged or one-inch screwed connections, to be installed through a packing gland and a ball valve. The packing gland shall have a 1-1/4-inch NPT connection, a packing compression collar, and a split ring locking collar. The sensor shall sense mass flow and automatically compensate for all specific changes in temperature and pressure. The sensor shall consist of two matched platinum resistance temperature detector (RTD) elements, (one heated and the other passive), sheathed in a [nickel] [gold] brazed [Type 316 stainless steel] [Hastelloy C-276] insertion assembly. The gas flow shall pass directly over sheathed elements without the need for an indirect. The sensor probe assembly shall be mounted in a [cast iron] [aluminum] enclosure, approved for Class 1, Groups C and D hazardous areas. The meter shall have the following characteristics:

1. Accuracy - ± 1 percent (at 30 degree F)
2. Repeatability - ± 1 percent of full scale
3. Turndown ration - 100:1 (max)
4. Signal output - 4-20 mA, 600 ohms max. load
5. Power input - 115 VAC, ± 15 VAC, 16 watts max.
6. Pressure rating (psi) - up to 1000 psig
7. Probe temperature rating - minus 50 to plus 330 deg. F (probe) (deg. F)
8. Accuracy - ± one percent of full scale

9. Gas flow velocities - 0.5 to 200 feet per second

The electrical components shall be [meter-mounted] [remote mounted] in a NEMA [4X] [Class 1, Groups C and D] [explosion-proof] enclosure, with flow indicator and totalizer, Factory Mutual and CSA approved for hazardous locations. The electronics shall read flow in SCFM with digital display. [8-conductor interconnection cable shall be provided between sensor and remote electronics]. The unit shall be adjustable in the field for span and zero to narrow the output range. All wetted parts of the sensor assembly shall be made of [Type 316 stainless steel with nickel braze] [Hastelloy C with gold braze]. Electronic enclosures shall be fiberglass, Type 316 stainless steel for NEMA 4X, or cast iron or aluminum for explosion-proof designations. The CONTRACTOR shall furnish one calibrator. The calibrator shall plug into the main circuit board in lieu of the sensor probe and shall provide simulation of the differential resistance signal produced by the flowmeter's sensor.

The following mass flow gas measuring systems shall be provided:

Tag No.	Service	Pipe Size	Range	Line Pressure	NEMA Rating

2.5 FLOW DETECTION SWITCHES

A. **Vane Flow Switches:** Vane flow switch shall utilize the motion of the vane to attract a magnet which actuates a micro switch. Switch shall be SPDT snap-action with contacts rated at 10 Amps, 110 Vac. The switch actuating magnet shall reside in a sealed body. Proof-pressure rating of the entire switch shall be 1000 psi. The following vane flow detection switches shall be provided:

Tag No.	Size	Trip Set Point	NEMA Rating

B. **Thermal Flow Switches:** Flow switches shall be thermally activated based on heat transfer between probes in the pipe flow stream. The probes, electronic circuits and relay shall all be part of an integral unit with a non-ferrous cast housing. Process wetted parts shall be 316 stainless steel. In horizontal pipe runs the unit shall be side mounted. All switches shall be equipped to function in an environment where the probes are not always immersed. Output relay shall be configurable to energize on increasing decreasing flow and have SPDT contacts rated 2 Amps @ 120 Vac minimum. Contact transfer point shall be field adjustable from .015 to 5 ft/sec in water. Response time shall be adjustable from 1 to 150 seconds. The trip flow point shall not

be affected by process fluid changes in the range of 32 to 140 degrees F and shall have a repeatability of ± 5 percent. The contract unit shall operate with the specified repeatability in an ambient temperature range of 25 to 120 degrees F. The power supply shall be [24 VDC] [120 Vac]. The following thermal flow detection switches shall be provided:

Tag No.	Size	Trip Set Point	NEMA Rating

C. **Ultrasonic Doppler Flow Switch:** The system shall consist of a flow element, switch control box, and connecting cable. The flow element shall be an ultrasonic Doppler non-invasive type. The flow element shall be attached to the outside of the pipe with a coupling compound furnished with the switch. The control box shall contain set point adjustment (0.5 to 20 fps), an adjustable relay dropout timer used to eliminate false alarms and relay chatter (0 to 60 seconds), and a low flow indicator. Switching differential shall be 0.8% of span. Output contacts shall be DPDT rated at 3 amps, 120 Vac. Contacts shall be hermetically sealed. The control box shall operate on 120 Vac. The control box shall be suitable for operation in an environment of -10 to 140 degrees F, 0-100% relative humidity. The transducer shall be suitable for operation in an environment of -30 to 300 degrees F. The switch response time shall be between 1 to 30 seconds. Connecting cable shall be armored and provided in lengths suitable for each location.

The following Doppler flow detection switches shall be provided:

Tag No.	Service	Trip Set Point	Pipe Size	NEMA Rating

2.6 LEVEL MEASURING SYSTEMS

A. Differential Pressure Level Measuring Systems: Level transducers shall be flanged, differential pressure sensing units. Transmitters shall be two wire devices with continuously adjustable span, zero and damping adjustments, integral indicator scaled in engineering units, solid state circuitry, and 4-20 mA output. Accuracy shall be ± 0.25 percent of span. Process wetted parts of the transducer shall be 316 SS. Flanges shall be 316 SS, 150 lbs rated. The low pressure connection shall be ½-inch NPT.

The following differential pressure level measuring systems shall be provided:

Tag No.	P&ID	Service	Range	Flange Size	NEMA Rating

B. **Ultrasonic Level Measuring Systems:** The meter shall be a non-contact, ultrasonic echo-time measuring device suitable for 120-volt, 60-Hz power supply. It shall consist of an ultrasonic transducer element assembly and a remote transmitter unit interconnected by manufacturer-supplied coaxial cable. Cable length shall be to accommodate the instrument locations shown on the Drawings. The system shall utilize 1,500-volt peak minimum energy level on the transducer and shall be suitable for measuring liquid surfaces from 1 to 25 feet below the transducer. The meter shall incorporate a reference reflector to provide instantaneous sound velocity compensation and it shall utilize microprocessor circuitry to process echo times for elimination of stray echoes and, where indicated, to provide linearization functions. The ultrasonic level meter shall produce a narrow beam angle of not more than 7 degrees total included angle. The ultrasonic sensor system shall have temperature compensation circuitry operable over the range of -40 degrees C to +50 degrees C, and shall be encapsulated to ensure a Class 1, Division 1 hazard rating. The sensor shall be unaffected by condensation and shall be provided with an integral heater, unless otherwise noted. The transmitter shall have a six digit display for level and "echo-lost" indication, and shall produce a 4 to 20 mA output signal into 750 ohms, maximum. The entire system shall be accurate within ± 0.1 foot of range. Meter shall have five Form C contacts. The meter shall be provided with an 8" flange with Teflon facing unless otherwise noted.

The following ultrasonic level measuring systems shall be provided:

Tag No.	Service	Range	Distance to Liquid Level (Min)	Distance to Liquid Level (Min)	NEMA Rating

C. **Capacitance-based Level Measuring Systems:** The level measurement system shall consist of a sensing element (rigid or flexible), a two-wire electronic transmitter, a three terminal inter-connecting cable, and radio frequency filters. The transmitter shall be a solid state unit with 4-20 mA output into 500 ohms (minimum), linear to level. The transmitter shall have non-interacting zero and span controls, a local indicator scalable in the desired process variable. The level measurement shall not be affected by changes in process conductivity or by more than 3" with a 1/32" coating build-up of a 1000 Fmho material on the sensing element. The transmitter shall measure the capacitance/admittance generated by the process on the sensing element. The sensing element shall be chemically resistant to the process material. It shall be supplied with a concentric supplemental ground rod when used in non-metallic vessels. The sensing element shall be flange mounted. The flange shall be chemically resistant to the process and, if necessary, contain either the concentric shield or ground rod. Length shall be as specified or shown on the drawings. The inter-connecting cable shall be a temperature stabilized coaxial cable with molded ground. The cable shall be capable of field shortening without affecting the system calibration, and shall be intrinsically safe. RFI filters shall be supplied by the system manufacturer and shall be field mounted on the sensing element input and transmitter output.

The following capacitance-based level measuring systems shall be provided:

Tag No.	Service	Range	Process Connection	Sensing Element Length

D. **Submersible Transducer Level Measuring Systems:** The level measurement system shall consist of a submersible transducer, electronic transmitter, support cable, and interconnecting cable. The submersible transducer shall be the strain gage type suitable for sensing pressure equivalent to the liquid level range indicated. The transducer shall have 316 stainless steel process wetted parts and shall be furnished with a waterproof interconnecting cable. The transducer shall be suspended by a corrosion resistant cable as recommended by the manufacturer. The installation shall allow easy removal of the transducer and cable assembly for maintenance purposes. The electronic level transmitter shall be remote mounted and shall produce a 4-20 mA DC signal linearly proportional to the level range indicated. The unit shall be complete with enclosure, zero and span adjustments and the measurement system shall be suitable for operation over a temperature range of 32 to 122 degrees Fahrenheit with an accuracy of ± 0.5 percent of span.

The following submersible level measuring system transducers shall be provided:

Tag No.	Service	Range	NEMA Rating

E. **Float Actuated Level Measuring Systems:** The level transmitters shall utilize a tape or cable suspended float to measure level. The transmitter shall be housed in an enclosure and the float and cable or tape shall be constructed of corrosion resistant materials. The transmitter shall produce a 4-20 mA signal into 700 ohms minimum. The transmitter output signal shall be within ± 1 percent of span from 20 to 100 percent of the indicator. The transmitter shall be furnished with a level indicator. The indicator shall be scaled in engineering units corresponding to the level measurement. Transmitter input power shall be 120 VAC 60 Hz.

The following float actuated level measuring systems shall be provided:

Tag No.	Service	Range	NEMA Rating

F. **Motorized Float Level Measuring Systems:** The level sensing unit shall utilize a tape or cable suspended float to measure level. Tension on the float shall be maintained by a motor. Counter weighted systems are not acceptable. The level sensing unit housing shall be constructed of corrosion resistant materials. The float, tape or cable, and process wetted parts shall be 316SS. The sensing unit shall include a mechanically operated level indicator and transmitter. The level sensing unit shall be top of tank mounted or ground level mounted as shown on the drawings. The unit shall be furnished with all sheaves and mounting brackets required for the installation. The tape or cable shall be contained within pipe from the level sensing unit to the top of the tank. The level transmitter shall produce a 4-20 mA signal proportional to level into 600 ohms minimum. Accuracy shall be within ± 0.75 percent of full scale. Input power shall be 120 VAC 60 Hz.

The following motorized float level measuring systems shall be provided:

Tag No.	Service	Range	NEMA Rating

2.7 LEVEL DETECTION SWITCHES

A. **Induction Level Switch:** Switches shall be of the induction type. Where probe length is over 6 feet, electrodes shall be stainless steel supported by suspension cables, terminated at vendor-supplied electrode fittings in a watertight housing. Where electrode length is less than 6 feet, electrodes shall be stainless steel rods insulated with a Teflon sheath. Each induction relay shall be a combination of a matched transformer and relay, integrally mounted on a common baseplate and connected to electrodes indicated. Transformer secondary voltage shall be as required by the liquid material.

The following induction level switches shall be provided:

Tag No.	P&ID	Service	Range	NEMA Rating

B. **Displacer Level Switches:** Switch shall consist of one or more porcelain displacers supported

on Type 316 stainless steel rod or cable suspended on a spring. Switch actuating mechanism shall be a magnetic shunt carried within a nonmagnetic sealing tube. Switch shall be operated by a magnet on the outside of the sealing tube. Switch shall be provided with carbon steel cage and flanged closure and process connections. Process connection shall be 2-inch flange, ANSI B16.5, Class 300, raised face, or as indicated.

The following displacer level switches shall be provided:

Tag No.	P&ID	Service	Range	NEMA Rating

C. **Inverted Column Level Switches:** High level flood switches shall be the type that traps air in an inverted column. Contact transfer is initiated by a pressure switch which is actuated by increasing pressure in the column. The pressure switch shall be isolated from the process with a diaphragm. Switch contacts shall be SPST N.O. with 5 Amps 120 VAC rating minimum. Switch enclosure and compression bell shall be aluminum connected by a one-foot steel pipe.

The following inverted column level switches shall be provided:

Tag No.	Service	Trip Level	NEMA Rating

D. **Conductance Level Switch:** Switch shall be of the conductance type with PVC sheath and 0.25-inch stainless steel rod electrodes for lengths up through 6 feet. For lengths greater than 6 feet, wire suspension type with stainless steel shield electrodes shall be provided. Electrode fitting enclosure shall be an epoxy coated and gasketed cast aluminum housing of suitable configuration for the application. Induction relays shall be two winding type. Primary power supply shall be 120 volts, 60 Hz. Secondary potential shall not exceed 300 volts AC and short circuit current shall not exceed 25 milliamperes.

The following conductance level switches shall be provided:

Tag No.	Service	Trip Level	NEMA Rating

E. **Intrusive Ultrasonic Level Switches (Single Point Detection):** Intrusive ultrasonic single

point level switches shall consist of a sensor, related electronics, and a control relay. The ultrasonic level switches shall transmit a high frequency signal through the gap of an invasive transducer. When the liquid fills the gap, the signal actuates the control output. As the liquid level falls, the signal attenuates in air and deactivates the control output. An integral signal averaging circuit shall inhibit false signals attributed to effervescence, splashing, or turbulence. All wetted parts shall be constructed of 316 stainless steel. All remote mounted units shall be provided with connecting cable provided by the manufacturer of the switches. The switch shall be SPDT with a minimum rating of 10 Amps at VAC or 5 Amps at 24 VDC. Repeatability shall be 0.1-inch or less with a response time of less than one second.

The following intrusive ultrasonic level switches for single point detection shall be provided:

Tag No.	Service	Mounting	Probe Length	Trip Level	NEMA Rating

F. **Intrusive Ultrasonic Level Switches (Two Point Detection):** Intrusive ultrasonic two point level switches shall consist of a sensor, related electronics, and a control relay. The ultrasonic level switches shall transmit a high frequency signal through the gaps of an invasive transducer. When the liquid fills each gap, the signal actuates the control output. As the liquid level falls, the signal attenuates in air and deactivates the control output. An integral signal averaging circuit shall inhibit false signals attributed to effervescence, splashing, or turbulence. All wetted parts shall be constructed of 316 stainless steel. All remote mounted units shall be provided with connecting cable provided by the manufacturer of the switches. The switch shall be SPDT with a minimum rating of 10 Amps at 120 VAC or 5 Amps at 24 VDC. Repeatability shall be 0.1-inch or less with a response time of less than one second.

The following intrusive ultrasonic level switches for two point detection shall be provided:

Tag No.	Service	Mounting	Probe Length	Trip Level	Trip Level	NEMA Rating

G. **Intrusive Ultrasonic Level Switches (Three Point Detection):** Intrusive ultrasonic three point level switches shall consist of a sensor, related electronics, and a control relay. The ultrasonic level switches shall transmit a high frequency signal through the gaps of an invasive transducer. When the liquid fills each gap, the signal actuates the control output. As the liquid level falls, the signal attenuates in air and deactivates the control output. An integral signal averaging circuit shall inhibit false signals attributed to effervescence, splashing, or turbulence. All wetted parts shall be constructed of 316 stainless steel. All remote mounted units shall be

provided with connecting cable provided by the manufacturer of the switches. The switch shall be SPDT with a minimum rating of 10 Amps at 120 VAC or 5 Amps at 24 VDC. Repeatability shall be 0.1-inch or less with a response time of less than one second.

The following intrusive ultrasonic level switches for three point detection shall be provided:

Tag No.	Service	Mounting	Probe Length	Trip Level	Trip Level	Trip Level	NEMA Rating

H. **Non-Intrusive Sonic Level Switches:** Non intrusive sonic level switches shall consist of a transducer, transmitter/receiver, and control relays. The sonic level switch transmitter shall generate pulses which are directed to the liquid level. The returning echo/signal shall be detected by the receiver. A microprocessor shall amplify and convert the signal into a digital representation of the distance from the reflecting surface. An output is produced when manually inputed trip values are exceeded. The microprocessor-based electronics shall enable user selection of range, span, setpoints, time delay, units of distance, and selectable failsafe mode. Relay setpoints shall be adjustable over the entire span without the use of reference targets. Automatic temperature compensation circuitry shall be incorporated. The transducer housing shall be PVC with corrosion resistant sensor element. All remote mounted units shall be provided with connecting cable provided by the manufacturer of the switches. Input power shall be 120 VAC. Switches shall be SPDT with a minimum rating of 10 Amps at 120 VAC. Repeatability shall be 0.1-inch or less with a response time of less than one second and an accuracy of plus or minus 0.25 percent of full scale.
The following non-intrusive sonic level switches shall be provided:

Tag No.	Service	Mounting	Trip Level	Trip Level	NEMA Rating

I. **Side-Mounted Float level Switches:** Liquid level switches shall be the side mounted float actuated type. Float switches shall be SPDT and shall consist of a fixed sealed reed switch actuated by a floating magnet. Level switches shall be flange or plug mounted to suit field requirements. Process wetted materials shall be plastic and/or 316 stainless steel.

The following side mounted float-type liquid level switches shall be provided:

Tag No.	Service	Trip Level	NEMA Rating

J. **Paddle Level Switches:** Paddle level switches shall consist of a rotating paddle that transmits an output when paddle movement has been stopped by the buildup of solid material. The paddle and all wetted parts shall be constructed of 316 stainless steel. The switch shall be snap acting, DPDT, with a minimum rating of 10 Amps at 120 VAC.

The following paddle level switches shall be the following:

Tag No.	Service	Trip Level	NEMA Rating

2.8 PRESSURE MEASURING SYSTEMS

A. **Electronic Pressure Transmitters:** Electronic pressure transmitters shall be two wire devices with continuously adjustable span, zero ad damping adjustments, integral indicators scaled in engineering units, solid state circuitry and 4-10 mA outputs. Accuracy shall be plus or minus 0.25 percent of calibrated span. Process wetted and body materials shall be 316 SS. Process connections shall be ½-inch NPT.

The following electronic pressure transmitter systems shall be provided:

Tag No.	P&ID	Service	Range	NEMA Rating

B. **Local Pressure Measuring Systems:** Pressure gauges shall be installed on suction and discharge connections to pumps; on discharge connections from blowers and compressors; at each side of pressure reducing valves; and where otherwise indicated. Vacuum gauges and compound gauges, where indicated, shall be installed on vacuum pumps. Gauges shall have Type 316 stainless steel movement and stainless steel or alloy case. Except as otherwise indicated, gauges shall have a 3-1/2-inch dial, 1/4-inch threaded connection, a Type 316 stainless steel snubber adapter, and a shut-off valve. Gauges shall be calibrated to read with an accuracy of ± 1 percent to 150 percent of the indicated pressure. Gauges shall be vibration and shock resistant. Gauges on liquid service should have cases filled with a suitable liquid. Gauges attached to systems containing chemical solutions, corrosive fluids, sludge, sewage, or other liquids containing solids, shall be equipped with diaphragm seals, or equal protective pressure or vacuum sensing devices, and comply with the following:

1. For: sewage, sludge, liquids containing Seals shall be fabricated with Type 316

	solids, pulsating flow	stainless steel, with stainless steel diaphragm for pressures over 15 psi, and elastomer diaphragm for pressures of 15 psi and below with Type 316 stainless steel nuts and bolts, fill connection and valved flush port size ¼-inch N.T.P., capable of disassembly without loss of filler fluid.
2.	For: chlorine and sulfur dioxide under pressure	Seals shall be fabricated with carbon steel with silver diaphragm and shall be rated at 800 psi.
3.	For: chemical solutions, low pressure sewage and chemical sludge except as otherwise indicated	Seals shall be fabricated with PVC body for removable mounting and rated at 200 psi, with Type 316 stainless steel bolts and nuts, ½-inch inlet, ¼-inch outlet, liquid-filled with Teflon diaphragm for pressure service and proper elastomer diaphragm for vacuum service.

The following pressure gauges shall be provided:

Tag No.	Service	Process Connection	Range

C. Diaphragm Seals for Pressure Measuring Systems: Diaphragm seals shall consist of bottom housing, lower ring, diaphragm capsule, fill screw, flushing connection, and a top housing. The diaphragm seal shall attach to the inlet connection of a pressure instrument to isolate its measuring element from the process fluid. The space between the diaphragm and the instruments pressure element shall be solidly filled with a suitable liquid. Displacement of the liquid fill in the pressure element through the movement of the diaphragm shall transmit process pressure changes directly to a gauge, transmitter, switch or any other pressure instrument. The diaphragm seal shall have a removable bottom housing to permit the servicing of the need to refill. All exposed surfaces, housings, and diaphragm shall be constructed of 316 stainless steel.

The following diaphragm seals shall be provided:

Tag No.	Process Connection	Instrument Connection	Fill Fluid

D. **Annular Ring Seals for Pressure Measuring Systems:** Where seal elements are used to

isolate pipeline flow media from a gauge the sensor shall be flanged and bolted directly into ANSI flanged pipelines. Face to face shall not be greater than a wafer style of a butterfly valve. The flanges shall have thru bolt holes to enable positive alignment in the pipeline. Flanges shall conform to pipe specifications. Inside diameter of the sensor shall be the same as the mating pipe with a full thru uninterrupted flow. There shall be no dead ends or crevices and flow passage shall make the sensor self-cleaning. Wetted parts (liner) shall be capable for continuous duty handling a slurry containing up to 15% solids. The Pressure Sensing Ring shall measure pressure for 360 degrees F around the full inside circumference of the pipeline. The sensing ring shall also be clamped into the body for the full radial width of the sensor. Pressure shall be transmitted to the gauge by a locked in and sealed fluid such as ethylene glycol or silicone oil. The sensor shall have an auxiliary tapped and plugged port to allow connection or other equipment.

The following annular ring seals shall be provided:

Tag No.	Service	Range	Size	Fill Fluid

2.9 PRESSURE DETECTION SWITCHES

A. Diaphragm Piston Pressure Switches: Pressure switches shall consist of a pressure transducer and a precision switch. Pressure transducer shall be the diaphragm piston type with wetted materials as recommended by the switch manufacturer. Piston shall be backed by a cylinder disc to permit 10 times over range pressure without affecting calibration. Range spring and piston shall be isolated from process fluids by the diaphragm. Switch shall be provided with two 3/4-inch conduit connections. The pressure transducer shall be selected so that setpoint falls between 30 and 70 percent of maximum range. Approximate setpoint and, if applicable, reset point shall be indicated on calibrated scales. Repeatability and sensitivity shall be 1.0 percent of operating range or better. Unless otherwise specified, switches shall be non-adjustable deadband type.

The following pressure switches shall be provided:

Tag No.	P&ID	Service	Trip Setting	NEMA Rating	Diaphragm Seals Required

J. **Differential Pressure Switch:** Differential pressure sensing switches shall be single-pole, double-throw with an adjustable differential range. Minimum differentials shall be less than 10 percent of range. Differential pressure switches shall be able to withstand surge pressure 1.5 times range or better. Each pressure switch shall have a visible scale contact operation. Pressure switches shall have a contact rating of 10 amperes at 125 volts AC. Pressure switches shall be snap-action switches and shall be in general purpose enclosures. A 316SS three valve manifold shall be supplied with each switch.
The following differential pressure switches shall be provided:

Tag No.	P&ID	Service	Range	NEMA Rating

2.10 TEMPERATURE MEASURING SYSTEMS

A. **RTD Temperature Measuring Systems:** Temperature transmitters shall be two wire devices with continuously adjustable span and zero adjustments, integral direct reading indicator, solid state circuitry and 4-20 mA output linearly proportional to the specified temperature span. Accuracy including temperature element shall be ± 0.1 percent of span. The temperature sensor shall be a spring loaded platinum RTD with Type 316 stainless steel Thermowells. The RTD and Thermowells length shall be as required or as indicated. The RTD and Thermowells shall be directly or remotely mounted as indicated. All necessary RTD wire shall be provided in conformance with the instrument manufacturer's recommendations.

The following RTD temperature measuring systems shall be provided:

Tag No.	P&ID	Service	Range	Mounting Integral/Remote	NEMA Rating

B. **Bimetallic Dial Temperature Measuring Systems:** Temperature indicators shall have 5-inch nominal diameter "all single" indicating scales, Type 316 stainless steel stems, and be suitable for stainless steel wells. Accuracy shall be plus or minus 1 percent of full range.

The following bimetallic temperature measuring system shall be provided:

Tag No.	P&ID	Service	Range	NEMA Rating

C. **Thermowells:** Unless indicated otherwise, Thermowells shall be provided for the following:

1. As part of a thermocouple or resistance bulb assembly
2. For a filled system
3. For test wells
4. For dial thermometers

All Thermowells shall have a ½-inch NPT female thread for connection of the measuring element. Well mounting connections may be screwed, socket-welded, or flanged. Screwed connections shall be 3/4-inch or 1-inch NPT. flanged connections shall be 1-1/2-inch minimum. Socket-weld connections shall be 1-inch or 1-1/2-inch.

Thermowells shall be bored from solid barstock with a minimum thickness of 3/16-inch. The well material shall be Type 316 stainless steel unless indicated otherwise. Well lengths are based on vessel or pipe size.

2.11 TEMPERATURE DETECTION SWITCHES

A. **Capillary Temperature Switches:** Temperature sensing shall utilize a SAMA Class II vapor pressure thermal system. The temperature sensor shall be either rigid, direct mounting type or remote mount type utilizing armored stainless steel capillary, as required by the specific application. Setpoint repeatability shall be no more than plus or minus one percent of span and deadband shall be adjustable plus or minus 18 degrees F. The switch mechanism shall be hermetically-sealed, SPDT type, rated 5 amperes at 120 VAC. Terminal blocks shall be provided for external wiring. The complete thermal system shall be 316 stainless steel and the minimum bulb length shall be 3 inches. The temperature switch shall be provided with 316 stainless steel Thermowells and bushing suitable for the thermal sensor. Thermowells shall have a minimum wall thickness between bore and outside of well of 3/16 inch. Materials shall be ANSI Type 304 or 316 stainless steel, unless exception is made due to the particular requirements of the process. Flanged Thermowells, when required, shall meet all requirements of material and size specified for that classification. Thermowells insertion length (U dimension) shall be selected for each application so as not to exceed the manufacturer's published allowable length/line velocity recommendations.

The following capillary temperature detection switches shall be provided and installed:

Tag No.	Service	Range	Setpoint	Process Connection	Mounting Integral/Remote	NEMA Rating

B. **Bimetallic Temperature Switches:** Temperature switches shall be bimetallic type with 0.750 in. NPT Thermowells process connection per applicable piping code. Switches shall have SPDT contacts and be provided with an adjustable setpoint. The following bimetallic temperature

switches shall be provided:

Tag No.	Service	Range	Setpoint	Process Connection	NEMA Rating

2.12 PROCESS ANALYSIS MEASURING SYSTEMS

A. **Turbidity Measuring Systems (Integral Unit):** The turbidimeter analyzers shall have the capability of detecting Nephelometric Turbidity Units (NTU). The turbidimeter shall include an integral indicating transmitter with selectable ranges of 0-1, 0-3 and 0-30 NTU. The transmitter shall produce a 4-20 mA DC output signal corresponding to the span of the selected range and proportional to the measured turbidity. Accuracy shall be within plus or minus 2 percent of full scale. The analog indicator shall be scaled in NTUs corresponding to the selected range and shall be visible through a window in the transmitter enclosure. The turbidimeter sensor shall be suitable for on-line analysis. Secondary reference standards shall be included with each turbidity analyzer. Both the transmitter unit and sensor shall be suitable for surface mounting. The interconnecting cable between the transmitter unit and the sensor shall be supplied by the instrument manufacturer and shall be of sufficient length to allow proper installation of the cable.

The following integral turbidity measuring systems shall be provided:

Tag No.	P&ID	Service	Range	NEMA Rating

B. **Turbidity Measuring Systems (Non-Integral):** Turbidimeter shall consist of a turbidimeter body, a separate control unit, interconnecting cable, and unless otherwise specified, a sample pump with flow rate adjustment. All optical and hydraulic components shall be housed in the turbidimeter body which shall incorporate a built-in bubble trap. The turbidimeter body shall be powered from the control unit, shall be suitable for surface mounting, and shall be constructed of corrosion-resistant structural plastic. The control unit shall provide a digital LED display with four digits and automatic decimal positioning and shall provide a 4 to 20 milliampere signal linear with turbidity expressed in Nephelometric Turbidity Units (NTU). The linear output signal shall be programmable to span all or any portion of the 0 to 100 NTU range. The control unit shall contain two setpoint alarm systems fully adjustable over the entire range. A bubble rejection system shall be provided in the control unit and self-test diagnostics shall be provided to automatically indicate malfunctions. Accuracy shall be plus or minus 1.0 percent from 0 to 3 NTU and plus or minus 5.0 percent from 30 to 100 NTU. Resolution shall be 0.001 NTU. A Formazin Calibration Kit shall be furnished consisting of a 1 liter calibration cylinder simulating the turbidimeter body, a Ten Sette Pipet and a pint bottle of 4000 NTU Formazin Primary

Standard.

The following turbidity non-integral measuring systems shall be provided:

Tag No.	P&ID	Service	Range	NEMA Rating

C. **pH Measuring Systems**: pH measuring system shall consist of a preamplifier, measuring electrode, reference electrode, automatic temperature compensator, and solution ground electrode encapsulated in a single PES or vinyl ester housing. The measuring electrode shall be glass unless otherwise indicated. The reference electrode shall have a double junction and be gel-filled or have a salt bridge to isolate the standard solution from the process. Electrode assembly shall contain an integral preamplifier for conversion of the high impedance electrode signal to a low impedance signal for transmission to the transmitter. The output signal shall be of sufficient strength to allow transmission of up to 3000 feet without further amplification. Sensor shall be suitable for either mounting in a PVC flow-through assembly with a union coupler, or submerged, as indicated. Appropriate mounting hardware shall be provided. The transmitter shall accept the input signal from the sensor assembly and produce a 4-20 mA isolated analog output proportional to pH. Transmitter shall be housed in an enclosure suitable for pipe or wall mounting. Transmitter shall be provided with an analog or an LCD display. Power supply shall be 24 VDC via two-wire signal transmission with a load of 0 to 600 ohms (minimum). Each pH system shall be furnished with any additional maintenance materials that are required for sustaining the system in continuous operation for one year.

The following pH measuring systems shall be provided:

Tag No.	P&ID	Service	Range	NEMA Rating	Material

D. **Dissolved Oxygen Measuring Systems**: Dissolved oxygen analyzers shall employ the membrane electrolytic method with gold/silver electrodes and integral temperature compensation elements. Electrode assemblies shall be suitable for immersion and insertion service and shall accept mechanical agitators. Agitators shall be provided when indicated. Submersion assemblies shall be suspended in tanks from Type 304 stainless steel, 3/4-inch, Schedule 40 pipe. Pipe shall be supported as indicated. Transmitters shall be two wire devices with continuously adjustable span, zero and damping adjustments, integral indicators scaled in milligrams per liter, solid state circuitry, and 4-20 mA outputs. Accuracy shall be plus or minus 0.25 percent of span. Power supply shall be 24 volts DC from signal transmission circuit. Transmitter shall support an external load of 0 to 600 ohms or greater without requiring trimming

resistors. Analyzer output shall be galvanically isolated from the process and the analyzer case. Analyzers shall connect to the electrode assembly utilizing a 20-foot portable cord and receptacle system.

The following dissolved oxygen measuring systems shall be provided:

Tag No.	P&ID	Service	Range	NEMA Rating

E. **Ultrasonic Density Measuring Systems:** The density meter shall consist of a pair of ultrasonic transducers and an electronic control unit. The control unit shall generate an electrical signal which is converted to an ultrasonic signal at the transducer. The signal is directed across the pipe through the sludge where it is converted by the other transducer to an electrical signal in proportion to the sludge density. The received signal shall be amplified in the control unit and used to actuate a relay. The attenuation of sonic energy transmitted through a liquid shall be in proportion to the amount of entrained solids. The sensor shall consist of a vitreous or enamel-lined carbon steel pipe section, with ANSI B 16.5, class 150, raised face flanged ends, a valved flush connection, and externally mounted, removable ultrasonic transducers. A separate, wall-mounted indicating transmitter shall be provided in a NEMA [4] enclosure. The transmitter shall include an indicator graduated in percent density, a power switch, and a calibration control. The chassis shall contain a clearly-marked gain adjustment for density, with a range over which the gain adjustment is usable. Where four-wire transmitters are permitted, they shall be provided with a loop powered signal current isolator. The process pipe mounted detector and the indicating transmitter shall be inter-connected by a multiconductor cable in a flexible conduit. The density meters shall conform to the following design characteristics:

1. Power supply - 120 volts, AC, 60 Hertz
2. Output signal - 4 to 20 milliamperes into 0 to 600 ohms galvanically isolated
3. Measurement type - ultrasonic
4. Density range - one to 5 percent solids
5. Repeatability - within 0.5 percent solids
6. Response time - 10 seconds
7. Meter body - Schedule 40 steel pipe, glass or vitreous-enamel-lined
8. For outdoor location, only - Analyzer to have surge protection
9. For hazardous location, only -2-wire transmitter to be intrinsically safe with active intrinsic safety barrier

Output indicators shall be provided with all analyzers. If the analyzer does not include an integral

indicator, a 1-1/2-inch, 90 degree movement milliammeter enclosed in a NEMA 7 or 9 meter case shall be attached to the unit. Output indicators shall be calibrated in percent solids units and provided with tic marks at 8, 12, and 16 milliamperes. Milliammeter shall connect into the transmission circuit by means of banana jacks, and a permanently connected diode shall be provided to bypass the jacks if the meter is removed.

The following ultrasonic density measuring systems shall be provided:

Tag No.	Service	Pipe Size	Range	NEMA Rating

2.13 SAFETY MONITORING SYSTEMS

A. **Combustible and Toxic Gas (Electronic Type) Monitoring Systems:** The system shall consist of a monitor/readout unit and separate gas sensor units. The sensor units shall be capable of being located remote from the monitor/readout unit by up to 500 feet. Sensor units shall receive power from and send signals corresponding to gas values to the monitor/readout unit. The monitor/readout shall be the enclosed wall mount type. Each monitor/readout shall have the capability of monitoring two sensors of any type or mix. The enclosure shall be suitable for location in Class S1, Division 1, Group B, C and D locations as defined by the National Electric Code. Access to the enclosure shall be through a screw on type cover. Calibration shall be non-intrusive, and a calibration kit shall be provided. The cover shall have a window of sufficient size to allow the viewing of meters and indicating lights. Mounting brackets for the purpose of attaching the unit to a flat surface shall be provided. A sealed switch (switches) accessible from the outside of the enclosure shall be provided for the purpose of alarm relay reset and audible alarm silencing. The sensor units shall be in enclosures suitable for location in class 1, Division 1, Groups C and D classified area. When installed in locations not readily accessible, a dual condulet shall be provided. The sensor units shall have provisions for mounting to a wall or similar structure. To eliminate radio frequency interference (RFI) and electromagnetic interference (EMI) the signal from the sensor to the monitor shall be in digital format or frequency format. The manufacturer shall provide all required cable from sensor to monitor. The combustible gas sensor shall be the catalytic bead type. The sensor must have a demonstrated resistance to degradation by silicones and reduced sulfur gases (hydrogen sulfide). Hydrogen sulfide gas sensors shall be the electrochemical type. The sensor shall not require the periodic addition of reagents. All sensing elements (sensors) shall have a minimum useful life of one year. The supplier shall provide replacement sensor at no charge for any sensor that does not meet the minimum requirement. A 3-digit LED readout shall be provided for the purpose of displaying the value, in concentration, of each sensor. The monitor shall have a separate indicating light for caution, warning, and alarm for each gas sensor. The lights shall be color coded. Two separate alarm setpoint levels shall be provided for each sensor. The setpoints shall be independently adjustable for any value in the readout range. The setpoints shall provide signals to user interface relays. Alarm setpoints shall have the capability of providing the user a selection of latching or

non-latching mode. As a minimum, one relay for each setpoint level shall be provided. All relays shall be Form C, single-pole, double-throw. Contacts shall be rated for 5 amps resistive at 120 VAC. The contacts shall be capable of being selected normally open or normally closed and normally energized or normally de-energized. A relay shall be provided to indicate trouble when any of the following conditions exist: system power loss, signal loss from a sensor, or 15 percent or greater under range. The LED display shall display a separate unique character when an over range or greater than 10 percent under range condition exists. An audible horn, buzzer, or tone shall be provided when an alarm condition occurs. The following functions shall be accomplished using pushbutton-type controls readily accessible on the front panel: display or alarm setpoint level, resetting any alarm setpoint, temporarily disabling any specific sensor from affecting the system, silencing of audible alarm, resetting any latching relay if alarm condition is cleared, and lamp test. The system shall operate on 115 or 220 VAC 50 or 60 Hz. Power shall not exceed 100 VA. The system shall require no periodic maintenance other than periodic checking of sensor unit function. Periodic sensor checking or actual adjustment of the sensor units shall be capable of being accomplished by one person at the sensor unit location. Gas monitor shall be UL approved.

The following electronic type of combustible and toxic gas monitoring systems shall be provided:

Tag No.	Parameter	Range	Alarm Setpoint	NEMA Rating

B. **Combustible and Toxic (Pumped Sample Type) Monitoring Systems:** The combustible gas detection system shall consist of an indicating monitor unit and separate gas sensor units. The gas sensor unit shall be capable of being located remote from the indicating monitor unit. The sensor unit shall receive power from and send a gas concentration signal to the indicating monitor unit. The signal shall be in a digital or frequency format to eliminate radio frequency or electromagnetic interference. The indicating monitor and remote sensors shall be designed for easy one man calibration. The indicating monitor shall be housed in a [NEMA 4X] enclosure with a shatterproof window of sufficient size to view the readouts and the lights. Each indicating monitor shall be suitable for simultaneously indicating the combustible gas concentration of [two] remote mounted sensors. Each of the [two] channels shall have a three digit LED display of the actual gas concentration value measured and individual alarm lights for up to three manually adjustable setpoints. Each of these [three] alarm points shall have individual contacts rated a 5 amperes at 120 VAC for remote alarming. The indicating monitor shall also have an additional contact output which is a common trouble alarm and is activated by failure of one of the sensors or system power loss. The indicating monitor shall operate, and provide required power to the sensors, on a 120 VAC power source. The gas sensor shall be a pumped, remote sampling system powered from the indicating monitor specified above. The gas sensor and the sample pump shall be housed in a [NEMA 4X] enclosure with integral sample flowrate indication. The enclosure shall provide a 1/4-inch NPT connection for the sample suction line and include a three-way valve and 1/4-inch NPT connection port for calibration gas. All tubing, valves and

communication cables required for these systems shall be provided by the manufacturer. The sample pump shall be capable of drawing a process gas sample continuously from a source which is at 5 inches w.c. vacuum. The sensor shall be of the catalytic bead type and be resistant to poisoning by hydrogen sulfide or silicones in the gas sample stream. One set of calibration equipment shall be provided for this project. The equipment shall include all components necessary to test and calibrate the combustible gas sensors and monitors specified. Calibration shall be based on a sample gas of known concentration. 0.6% propane in air shall be the basis of calibration. The calibration kit shall include flow control gas regulator, connection tubing, two cylinders of sample gas, and a universal electronic calibrator module.

The following sample pump type combustible and toxic ambient gas monitoring systems shall be provided and installed:

Tag No.	Parameter	Range	Alarm Setpoint

C. **Chlorine Gas Monitoring Systems:** Chlorine gas leak detectors shall be designed for mounting in the monitored space and shall provide localized warning and alarm contact outputs in the presence of chlorine gas concentration at setpoints adjustable between 1 and 10 parts per million (ppm). Detector power supply shall be 120 volts AC, 60 hertz, and detector shall alarm in case of power failure. Each detector shall utilize a non-wet chemistry type, voltametric gas sensor requiring minimum maintenance and shall be sensitive to the pressure of chlorine gas only. The detector shall consist of a sensor and alarm module. The sensor shall not require reagents or require pumps to sample the air. Each sensor shall be supplied with cable as required. Warning and alarm activation shall be indicated with a light locally on the alarm module. The system shall be a "fail safe" in that all failures in the internal electrical circuit shall be annunciated. An alarm reset button and power on light shall be provided. The detectors shall be wall-mounted units. Electrical components shall be within gasketed enclosures with gas tight connections. Contact outputs shall be provided for warning and for alarm. Warning output shall be non-latching. Alarm output shall activate upon detection of gas at alarm setpoint, upon detection of internal failure, or upon detection of sensor failure and shall be field selectable for latching or non-latching. Contact outputs shall be rated 5 amperes at 120 volts AC minimum. The entire installation for each leak detector shall be designed to prevent radio frequency interference (RFI) and electro-magnetic interference (EMI). As a minimum, the alarm module and sensor shall be RFI shielded and the sensor cable shall be installed in rigid metal conduit. The shielding and the metal conduit shall be connected to earth ground. The manufacturer shall verify in writing that the units are properly installed and that the units will not alarm when the antenna of a 5 watt, 450 MHZ transmitter is activated at three feet from the alarm module or sensor with the alarm setpoint as low as one twentieth of full scale. Each leak detector shall be supplied with battery backup which will maintain normal operation of the leak detector for a minimum of 6 hours in the event of a power failure. The battery backup shall recharge while the unit is operating under normal power.

The following ambient chlorine gas monitoring systems shall be provided and installed:

Tag No.	Range	Alarm Setpoint	NEMA Rating

D. **Sulfur Dioxide Gas Monitoring Systems:** Sulfur dioxide gas leak detectors shall be designed for mounting in the monitored space and shall provide warning and alarm contact outputs in the presence of sulfur dioxide gas concentrations at setpoints adjustable between 1 and 10 parts per million (ppm). Detector power supply shall be 120 volts AC, 60 hertz, and detector shall alarm in case of power failure. Each detector shall utilize a non-wet chemistry type, voltametric gas sensor requiring minimum maintenance and shall be sensitive to the pressure of sulfur dioxide gas only. The detector shall consist of a sensor and alarm module. The sensor shall not require reagents or require pumps to sample the air. Each sensor shall be supplied with cable as required. Warning and alarm activation shall be indicated with a light locally on the alarm module. The system shall be "fail safe" with failures in the internal electrical circuit. An alarm reset button and power on light shall be provided. The detectors shall be wall-mounted units. Electrical components shall be within gasketed enclosure with gas tight connections. Contact outputs shall be provided for warning and for alarm. Warning output shall be non-latching. Alarm output shall activate upon detection of gas at alarm setpoint, upon detection of internal failure, or upon detection of sensor failure and shall be field selectable for latching or non-latching. Contact outputs shall be rated 5 amperes at 120 volts AC minimum. The entire installation for each leak detector shall be designed to prevent radio frequency interference (RFI) and electro-magnetic interference (EMI). As a minimum, the alarm module and sensor shall be RFI shielded and the sensor cable shall be installed in rigid metal conduit. The shielding and the metal conduit shall be connected to earth ground. The manufacturer shall verify in writing that the units are properly installed and that the units will not alarm when the antenna of a 5 watt, 450 MHZ transmitter is activated at three feet from the alarm module or sensor with the alarm setpoint as low as one twentieth of full scale. Each leak detector shall be supplied with battery backup which will maintain normal operation of the leak detector for a minimum of 6 hours in the event of a power failure. The battery backup shall recharge while the unit is operating under normal power.

The following ambient sulfur dioxide gas monitoring systems shall be provided and installed:

Tag No.	Range	Alarm Setpoint	NEMA Rating

2.14 CONTROL PANEL INSTRUMENTATION

A. **Bar Graph Indicators**: Indicators shall be the electronic gas-discharge type suitable for installation in flush panel mounting shelves. Indicator shall provide for two non-isolated input

circuits. Input signal level shall be 4-20 mA DC through a shelf-mounted 250-ohm resistor. The units shall contain an integral power supply suitable to energize two 4-20 mA DC, 2 wire transmitters. Unit power supply shall be 24 VDC. Indicator accuracy shall be plus or minus 0.5 percent of span with a repeatability of 0.1 percent of span. Indicator scales shall be in engineering units.

B. **Pointer Type Indicators**: Indicators shall be pointer type indicating meters suitable for panel mounting with a minimum scale length of 3 inches. Scales shall be calibrated in engineering units as indicated. Accuracy shall be plus or minus 2 percent of span. The unit shall accept an input of 4-20 mA DC or 1-5 VDC and shall have an input impedance of 100 ohms maximum.

C. **Indicating Fanfold Stripchart Recorders**: The indicator-recorders shall be sized approximately 7 inches wide by 7 inches high by 21 inches deep with a general purpose enclosure suitable for flush panel mounting. The recorder shall use a 4-inch fanfold chart with a minimum 16 day capacity. Both charts and indicator shall be scaled as indicated. Charts shall have time marks. The pen indicator mechanism shall be servo-operated without a clutch. Chart drive shall operate at a speed of approximately 3/4-inch per hour. The recorder shall be of solid state design and have one, two, or three tipped pens as indicated. Ink colors shall be: pen 1 - red; pen 2 - blue; pen 3 - green. Alarm and control contacts shall be furnished as indicated. Accuracy shall be plus or minus 0.5 percent of span. Input power shall be 120 VAC, 60 Hz. A supply of charts and pens for one year continuous operation shall be supplied with each recorder.

D. **Digital Indicators**:

1. Digital indicators shall be self-contained instruments that display process signals directly in engineering units. The unit shall be suitable for panel mounting and shall utilize an LED display where numerals are no less than [0.5-inch] height.

2. The input signal to the digital process indicator shall be 4-20 mA DC or 1-5 VDC. The input sample rate of the unit shall be a minimum of 2 per second. The unit shall have an auto-zeroing feature and shall have provisions for field adjustable scaling and offset. Accuracy shall be plus or minus 1 least significant digit. Input power to the digital indicator shall be 120 VAC, 60 Hz.

E. **Totalizers**: The totalizers shall be solid state C-MOS logic type with minimum 8 non-resettable LCD digits. Totalizers shall be approximately 2 inches high by 2 inches wide by 3 inches deep, suitable for front panel mounting. Character height shall be 0.140 inch minimum. Each totalizer shall have a standby battery capable of maintaining the last totalized value for a minimum of 72 hours after a utility power failure. Power supply shall be from transmission signal which shall be 6 to 250 volts AC or DC or DC switch closure. Maximum count speed shall be 3600 counts per minute.

F. **Current Alarm Trip Switches**: Current alarm trips shall be single or dual type as indicated. Units shall accept voltage or current input signals. Dead bands shall be factory set at 1.0 percent

of full span for dual trips and adjustable over 100 percent of span for single trips. Alarm trips shall be equipped with 10 A DPDT contacts. Alarm trips shall include setpoint dials calibrated 0 to 100 percent for each trip point. Single alarm trips shall include a dead band adjustment dial calibrated 0 to 100 percent.

G. **Selector and Pushbutton Switches:** Selector and pushbutton switches shall be rated 10 A at 600 volts, shall be heavy-duty, oil-tight, and shall have the number of positions and poles indicated. Operators shall be corrosion resistant.

H. **Indicating Lights**: Indication lights shall be incandescent push-to-test type and shall be heavy-duty, oil-tight. Each light shall have a screwed-on glass prismatic lens approximately 1-inch in diameter. Each light shall have a factory-engraved legend plate as indicated. Indicating lights shall be 120 VAC type with transformers for use with 6.3 volt lamps.

E. **Alarm Annunciator Systems**:

1. Alarm annunciator systems shall consist of a back lighted window display, alarm modules, flasher-audible modules, power supply, and horn. All annunciators which are installed in NEMA 3, 3R, 4, or 4X enclosures shall be protected by window kits which preserve the panels NEMA rating. Annunciator shall be furnished with (integral)(remotely mounted) acknowledge, test, reset, and silence, pushbuttons. The alarm sequence shall conform to ISA M-1 as follows:

   a. Alarm condition sounds the horn and causes the display to flash.

   b. Depression of the Acknowledge Pushbutton causes the horn to go silent and the display goes from flashing to continuously lit and remains illuminated until the alarm condition ceases to exist.

   c. Depression of the Reset Pushbutton, subsequent to the process condition returning to a normal condition, returns the sequence to a normal state.

   d. Depression of the Test Pushbutton shall simulate simultaneous abnormal process conditions on all related alarm points to reveal lamp or circuit failures.

2. **Alarm Modules:** Alarm point modules shall be solid state electronic devices. Each module's relay contacts shall be configured [normally open] [normally closed] to accept dry inputs. The annunciator shall provide [24 VDC] [48 VDC] [125 VAC] wetting voltage for all inputs. All input and alarm logic shall conform to the surge test immunity requirements of IEEE-472-1974. All solid state logic circuits shall conform to the requirements of SAMA PMC 33.1 "Electromagnetic Susceptibility of Process Control Instrumentation" in their ability to resist Radio Frequency Interference (RFI) with the control panel doors open. The time period between the operation of the field contacts and the annunciation of the alarm state shall not exceed 50 milliseconds. Each alarm module shall be field configurable for normally open or normally closed contact operation. [Time delay circuits, adjustable from [0.7 to 1] [.4 to 6] seconds shall be provided for [each

alarm point] [for indicated points] to prevent false operation due to extraneous circuit pulses or electrical transients]. Alarm modules and flasher-audible modules shall be easily removable for ease of inspection and servicing. Alarm logic shall be provided for all currently utilized and spare display points.

3. **Alarm Display:** Annunciator windows shall be translucent white with black letters. Annunciator cells shall be approximately 2"/50mm high and 3"/75mm wide. Each window shall have two high intensity 6 volt, 1 watt lamps rated at 20,000 hours. The lamps shall be wired so that the burnout of a lamp will not affect the other lamp. All lamps shall be replaceable from the front of the annunciator.

4. **WindowEngraving:** The window arrangement and associated text shown in the Contract Documents shall be interpreted as a guideline only which is subject to modification at the time of submittal by the Construction Manager. All lines of characters shall be centered in the window. All characters shall be engraved in the same size and line thickness all in conformance with the requirements of ISA-RP60.6 (Nameplates, Labels, and Tags for Control Centers) with a recommended viewing distance of 3'/1m to 6'/2m. All characters shall be in uniformly and symmetrically spaced to give a clear, easy-to-read, informative display. Each window shall have two high intensity 67 volt, 1 watt lamps rated at 50,000 hours. The lamps shall be wired so that the burnout of a lamp will not affect the other lamp. All lamps shall be replaceable from the front of the annunciator.

5. **Audible Alarm Horn:** Solid state tone generators shall be located in the annunciator or control panel enclosure. The adjustable tone generator shall activate an alarm [horn] [chime] [buzzer] [speaker] located on the front of the annunciator. The sound shall be [continuous] [intermittent] until silenced by manual pushbutton operation. The sound shall be adjustable between steady and fluctuating or warble. [The audible alarm shall silence automatically after an adjustable time.] Audible devices shall conform to the environmental requirements that apply to other panel mounted devices.

6. **Power Supply Systems:** Each annunciator shall be provided with its own dedicated redundant 24 VDC power supplies. The sharing of power supplies with panel power shall not be permitted. Power supplies shall provide electrical isolation between power sources and annunciator circuits. Ground detectors shall annunciate the occurrence of accidental circuit grounds. The power supply system shall enable the offending grounds to be located and removed without affecting the annunciator operation or the power source. The power supplies shall be redundantly configured with diode auctioneering to enable the transition between a failed power supply to the backup without impact to the annunciator and to enable the replacement of a failed supply without impact to the annunciator's operation. Power failure detectors shall be provided to alarm the failure of each power source and each power supply to an independent alarm device.

7. **Retransmit Contacts:** All alarm inputs to the annunciator and audible relays shall have retransmit contact outputs for input to other equipment. Retransmit contacts shall be a field contact follower and utilize gold flashed contacts rated at 5 amps at 24 VDC [or] [125

VAC and 0.1 amp at 125 VDC resistive.]

8. **Pushbuttons:** Annunciator pushbuttons shall be provided for Alarm Acknowledge, [Silence], Reset, and Lamp test functions as shown on the contract drawings. All pushbuttons shall be momentary manual switches that cause a change from one annunciator sequence state to another. Pushbuttons shall be heavy duty and conform to the environmental requirements that apply to other panel mounted devices. Pushbuttons shall be located to facilitate convenient operation and access while minimizing the possibility of accidental operation of other nearby pushbuttons. Interlocks shall be provided to (1) require the operation of the Acknowledge pushbutton prior to alarms being Reset (2) require operation of silence and acknowledge pushbuttons in sequence to avoid accidental loss of alarm indications.

J. **Proportional Plus Manual Reset Process Controllers:** Proportional plus manual reset controllers shall be microprocessor based single loop controllers. Units shall have front panel bar graph or digital indicators with scales in engineering units as indicated. Vertical process and setpoint bar graph indicators shall have accuracies of plus or minus 0.5 percent of span. Fully adjustable high and low alarm set points shall be provided as indicated. Alarm outputs shall be indicated on the face panel of the controller.

1. Units shall be suitable for operation for temperature variations from 40 to 120 degrees F and over a range of relative humidities from 10 to 90 percent.

2. Controllers shall operate on 120 VAC, 60 Hz. Power supplies, if required, shall be provided. All accessories required for adjustment of control parameters shall be provided. Enclosures shall be nominally 3 inches by 6 inches, suitable for separate or multiple panel mounting.

3. Controllers shall include manual-automatic selection, fully adjustable proportional plus manual reset modes, bumpless transfer switching, setpoint control and indications, high and low output limiters, controlled variable and output signal indicating scales. Controllers shall accept 4-20 mA input signals and output a similar signal. In the event of a power loss with controller in either automatic or manual mode, all controller settings shall return to the last value after power is restored. Proportional band shall be fully adjustable from 3 percent to 500 percent. Manual reset controls shall be continuously adjustable from 0 to 100 percent of scale. Controllers shall include manual increase/decrease pushbuttons. Indicated controllers shall include a remote setpoint feature including a remote/local selector switch. Remote setpoint input signal shall be 4-20 mA.

2.15 PROGRAMMABLE LOGIC CONTROLLER (PLC):

A. The CONTRACTOR shall furnish, install, program, test, calibrate, fully configure and place into operation Programmable Logic Controllers (PLCs) as specified herein.

B. The CONTRACTOR shall furnish all necessary interconnecting cables, all accessories, and all

appurtenances as indicated herein or as required for proper operation of the system. All major components of the system shall be of the same manufacturer. All equipment shall be capable of tolerating and capable of riding through a power interruption of 8 milliseconds or less without interruption of normal operation.

C. **Construction:** The PLC central processing unit (CPU) shall be of solid-state design. All CPU operating logic shall be contained on plug-in modules for quick replacement. Chassis wired logic is not acceptable. The controller shall be capable of operating in a hostile industrial environment (i.e., heat, electrical transients, RFI, vibration, etc.) without fans, air conditioning, or electrical filtering (up to 60 degrees C and 95 percent humidity).

D. **Design:** The PLC shall be furnished with I/O (input/output) modules suitable for the interface with the new and existing field devices. The I/O's shall be 4-20 mA signals for analog inputs and analog outputs and shall be 24 VDC and/or 120 VAC signals for discrete inputs and discrete outputs. The PLC shall provide internal fault analysis with a fail-safe mode and a dry contact output for remote location alarming, and a local indicator on the PLC frame in the event of a fault in the PLC.

E. Central Processor: The central processor shall contain all the relays, timers, counters, number storage registers, shift registers, sequencers, arithmetic capability, and comparators necessary to perform the specified control functions. It shall be capable of interfacing sufficient discrete inputs, analog inputs, discrete outputs, and analog outputs to meet the specified requirements plus an additional 25 percent excess capacity. The power supply shall contain capacitors to provide orderly shutdown in the event incoming power does not meet specifications. If this occurs, the processor shall cease operation, forcing all outputs off. The processor shall have a key type memory protect switch to prevent unauthorized program changes. The central processor shall be 32-bit, minimum.

F. Memory: The programmable controller memory shall be Complementary Metal Oxide Semi-conductor (CMOS) based memory with battery backup or Erasable Programmable Read-Only Memory (EPROM) based memory. The CMOS memory shall be a minimum of 21K with sufficient battery backup to retain the program during power interruptions of up to 1 year. An indicator shall show the status of the batteries. A reference shall be available through the discrete outputs to alarm the operator that the batteries should be changed.

The PLC shall be supplied with sufficient memory to implement the specified control function plus a reserve capacity of 25 percent of the total provided. This reserve capacity shall be totally free from any system use. The memory shall be programmed in a multi-node configuration with multiple series or parallel contacts, counters, timers, and arithmetic functions.

G. Controller: The controller shall be programmed in "ladder diagram" language. It shall be easily reprogrammed with a portable programming unit. The PLC system shall be programmed by the vendor to perform the specified control and monitoring functions. Two documented copies of the operating program shall be furnished which shall allow direct, step-by-step, reloading of the system program. Copies of this program shall be furnished in the format used in the contract

diagrams for conventional relay control systems. These diagrams shall reflect equipment name designations used in the PLC as well as the contract diagram equipment name designations (i.e., timer "Q" in the Contract drawing may become timer OL in PLC program).

H. **Power Supply:** The PLC power supply shall operate at the following:

1. 120V ac RMS plus or minus 15 percent continuously.

2. 120V ac RMS plus or minus 30 percent maximum 30 seconds.

3. 120V ac RMS plus or minus 100 percent maximum milliseconds.

4. Line spikes at 1000V ac (5000 micro-seconds duration; 0.05 percent maximum duty cycle).

I. **Input/Output Modules:** All I/O housings and I/O modules shall be of rugged construction with modules in place. Sufficient input and sufficient output modules shall be provided with the PLC to implement the specified control functions plus a reserve capacity of 25 percent of the total provided.

1. Discrete Input Modules: Defined as contact closure inputs from devices external to the programmable logic controller module. Input modules shall be shielded from short time constant noise and 60-Hz pickup. Individual inputs shall be optically isolated for low energy common mode transients to 1500 volts peak from user's wiring or other I/O Modules. The modules shall have LED lights to indicate a discrete input.

2. Discrete Output Modules: Defined as contact closure outputs for ON/OFF operation of devices external to the programmable logic controller module. The output modules shall be fused (typically 5-amp at 115V ac) with blown fuse indicator lights. The output modules shall be optically isolated from inductively generated, normal mode and low energy, common mode transients to 1500 volt peak. All output modules shall have LED lights to indicate output has been cycled ON by the controller.

3. Analog Input Modules: Defined as analog inputs for 1 to 5 VDC or 4 to 20 mA dc signals, where an analog to digital conversion is performed and the digital result is entered into the processor. New inputs shall be provided for every scan.

4. Analog Output Modules: Defined as analog output for 1 to 5 VDC or 4 20 mA dc signals, where a digital to analog conversion is performed and the analog result is produced as an output. New outputs shall be produced on every scan.

J. **Data Access Panel:** A Data Access Panel with LCD display and keypad shall be furnished to allow the operator to monitor and make changes in set point registers of internal timers and counters in the PLC. Program logic or sequence changes shall not be made from this panel unless a security code or key lock is used to prevent unauthorized changes. Interconnecting

cables between the Data Access Panel and the PLC shall be furnished.

K. **Programming Unit:** All programming shall be accomplished with a CRT programmer. The programmer shall be capable of being directly plugged into the PLC system without the requirements of additional hardware. All programming, all monitoring, all searching, and all editing shall be accomplished with the programmer. These function shall be capable of being done both "on line" while the processor is scanning or "off line" while the processor is not scanning. The programmer shall display multiple series and parallel contacts, coils, timers, counters, and calculation functions. The programmer shall also be able to monitor the status of all inputs, all outputs, all timers, all counters, and all coils. It shall have the capability to disable/force all inputs, all outputs, and all coils to simulate system operation. It shall also indicate "power flow" through all elements and include a search function to locate any element and it's program location. The processor status information, such as error indication and amount of memory remaining, shall be shown on the CRT screen. The programmer shall be of rugged construction and be portable, allowing it to be used in an industrial environment without special protection. The CONTRACTOR shall provide one new programmer complete with manuals to the OWNER to enable future system support. The device shall be turned over to the OWNER at START-UP.

L. **PLC Control System Software:** This Section covers the furnishing of standard and customized software, fully installed and fully configured in the control systems specified herein. It is the intent of this specification to have the PLC System Supplier furnish his latest generation, standard, field proven, fully debugged and supported software package for this application with a minimum of additions or changes. Customized or specially written software shall be furnished if required to meet all of the functional requirements specified herein. Any custom applications software required shall be fully integrated into the basic software and shall not require unique command structures. Software specified herein is described in broad, functional categories. The System Supplier shall furnish a complete software package including the functional requirements specified herein along with whatever additional software is required by the supplier for proper and efficient operation of the PLC Control System. No attempt has been made to list all software or list all characteristics of software required by the System Supplier to meet the functional requirements specified herein.

1. General: The software package shall provide a system capable of controlling system level activities and a higher level process control language allowing the operator to monitor and control the process through an interactive human interface. The software environment shall support a multi-programming atmosphere allowing concurrent execution of more than one program in a background/foreground mode or multi-tasking mode.

2. Throughout the execution of all software modules, the operator shall be presented with all of the command or operation choices available at that point in the program using sufficient verbiage or symbols to make the choices self-explanatory and unambiguous. Question and answer or fill-in-the-blank requests shall only be permitted where file names, tag names, or other unique text or numerical information is required.

3. System-level software shall include a real time operating system, a calendar/time program, a file management program and a system of diagnostic routines in addition to any compilers, editors, loaders, or assemblers required to support the process control software language.

4. All programs shall be self-configuring, such that they obtain the size and configuration of the system from parameters contained in the various files created during system generation. No parameters related to the hardware configuration shall be hard coded into any of the software.

5. System Level Software: System-level software shall include a complete and unmodified operating system furnished by the System Supplier that provides system-level functions as specified herein. Operating system software shall function automatically without operator intervention, except as required to establish file names and similar information.

6. Operating System Software: The real-time operating system software shall be the standard uncorrupted product of the host computer and shall provide the following minimum functions:

    a. Respond to demands from a program request or to demands from an operator.

    b. Dynamic allocation of the resources available in the system. These resources shall include main memory usage, computation time, peripheral usage, and I/O channel usage.

    c. Allotment of system resources on the basis of task priority levels such that a logical allocation of resources and suitable response times are assured.

    d. Queuing of requests in order of priority if one or more requested resources are unavailable.

    e. Resolution of contending requests for the same resource in accordance with priority.

    f. Service requests for execution of one program by another.

    g. Transfer data between programs as requested.

    h. Management of all information transfers to and from peripheral devices.

    i. Control and recovery from all program fault conditions.

    j. Diagnose and report real-time hardware device errors.

7. Program execution shall be scheduled on a priority basis. A multilevel priority interrupt

structure is required. A program interrupted by a higher priority program shall be entered into a list of pending programs. Its execution shall be resumed once it becomes the currently highest priority program. Initiation of programs shall, as a minimum, be activated in the following ways:

a. In response to external interrupts.

b. At a scheduled time of the day.

c. On an elapsed time interval basis.

d. On request by another program.

e. On request from the data access panel.

8. The system shall allow periodic programs to be scheduled. The allocation of resources to a time scheduled program shall be based on its relative priority ad the availability of computer system resources.

9. Start-up and Restart: Software shall be provided which initializes and brings a computer or any microprocessor based hardware unit from an inactive condition to a state of operational readiness.

   Initialization shall include determination of computer system status prior to start-up of initializing operating system software and initializing application software. Initialization shall also include the loading of all memory resident software, initialization of timers, counters, and queues, and initialization of all dynamic database values.

10. Shutdown: The software shall provide an orderly shutdown capability for shutdowns resulting from equipment failure, including computer processor failure, primary power failure, or a manually entered shutdown command. When the loss of primary power is sensed, a high-priority hardware interrupt shall initiate software for an immediate, orderly shutdown. When a shutdown occurs in response to a command or malfunction, the software shall control the affected hardware quickly and automatically to a secure state.

11. Diagnostics: Diagnostic programs shall be furnished with the software package to detect and isolate hardware problems and assist maintenance personnel in discovering the causes for system failures. The system manufacturer's standard diagnostic routines shall be used as much as possible. Diagnostic software and test programs shall be furnished for each significant component in the system.

    Diagnostic routines shall test for power supply, central processing unit, memory, and I/O bus failures as a minimum.

    a. Calendar/Time Program: The calendar/time program shall update the second,

minute, hour, day, month and year in the operating system and transfer accurate time and date information to all system level and application software. Variations in the number of days in each month and in leap years shall be handled automatically by the program. The operator shall be able to set or correct the time and date from the data access panel, only at the highest security level.

12. **Operator Interface**: System-level software shall provide for creation and modification of alphanumeric displays, compression of display information for storage, and linking of dynamic files to database variables. Each display screen shall be able to be made up of static and dynamic alphanumeric information. The system shall be furnished with standard displays as specified herein. The system shall be capable of storing and utilizing all standard display formats.

    Additionally, all display screens shall include a dedicated area that shall display the current time and date, and at lease one line for system-level messages.

13. Standard Displays: The operator interface systems shall include at least the following standard, non-configurable displays.

    a. Current Alarm Summary--As specified in the alarm processing section of this document.
    b .System Overview--Displaying the current status of major systems hardware components including the input/output hardware.
    c. Menu Displays--Indicating the various displays and application level choice available to the operator.
    d. Point Displays--Detailed displays in a standard format for all types of points in the system. Any point in the system shall be able to be displayed indicating all parameters associated with the point. Each entry in the display shall be labeled in engineering units.

14. Algorithms: System software shall support the implementation of algorithms for the determinations of control actions and special calculations involving analog and discrete inputs. These algorithms shall be capable of outputting positional or incremental control outputs or providing the product of calculations. The algorithms shall include alarm checks where appropriate. As a minimum, the following types of algorithms shall be provided.

    a. A calculator algorithm which performs functions such as summing several variables, raising to a power, roots, dividing, multiplying, and subtracting.

    b. A switch algorithm which reads the current value from its input address and stored it as the value of its output address. Two types of switches shall be accommodated, 2 outputs with one input and one output with 2 inputs.

    c. A 3 mode Proportional-integral-Derivative (PID) controller algorithm, with each of the 3 modes independently adjustable. The algorithm shall support both direct

and reverse acting modes.

d. Algorithms for lead, lag, dead time, and ration compensators.

e. Algorithms to perform integration and totalization of analog process variables.

Algorithms that drive the setpoint of a controller shall include provisions for bumpless transfer, which shall be implemented by use of a bias value.

Algorithms shall be implemented and modified in the system at any time through the use of interactive software modules in a manner consistent with other interactive modules and shall not required any direct source of code changes.

15. Alarm Processing

a. Alarm processing software shall be provided to recognize and report alarm events and conditions to the Local Control Board in an organized, unambiguous, clear, and convenient manner. Alarms shall be classified into at least 2 priority levels and at least 2 independent classes.

b. Alarm processing software shall generate alarms for the following conditions:

(1) Discrete input or output change of state is defined as an alarm in the control software.
(2) Analog value exceeding alarm limits defined in the control software.

(3) Analog rate of change exceeding limits defined in the control software.

(4) Failure of the PLC processor, mass memory device, process input/output hardware, or other major hardware component.

Alarms shall be generated in each case above at the time of occurrence and at the time the condition returns to normal.

M. **Testing:** The CONSTRUCTION MANAGER shall witness testing of the units. Solid-state logic systems shall be tested as complete assemblies. Testing of individual components or modules shall not be acceptable.

M. **Training:** A manufacturer's representative shall supply two 8-hour days of on-site training for the OWNER'S personnel. The training shall include but not be restricted to, operation of programming unit, trouble shooting of system hardware and software, and program development.

N. **Seven Day Acceptance Test:** After start up has been completed, the System shall undergo a 7-day acceptance test. The System must run continuously for 7 consecutive days. During this period, all System functions shall be exercised. Any System interruption and accompanying

component, subsystem, or program failure shall be logged for cause of failure, as well as time of occurrence and duration of each failure. A failure shall cause termination of the 7-day acceptance test. When the cause of a failure has been corrected, a new 7-day acceptance test shall be started.

Each time the CONTRACTOR's technician is required to respond to a System malfunction, he must complete a report which shall include details concerning the nature of the complaint or malfunction and the resulting repair action required and taken.

O. **Operations and Maintenance Manuals:** The CONTRACTOR shall furnish to the OWNER 5 complete sets of operation and maintenance manuals. The manuals shall include date, information drawings, etc., for the system, subsystem, and all components, and shall include names, addresses and telephone numbers of equipment suppliers, representatives and repair facilities.

This shall include a complete description of the recommended operating procedures, maintenance procedures, and spare/replacement parts list for equipment items with catalog data, diagrams, and drawings or cuts describing the equipment. Each set shall include full size assembly and wiring diagrams; drawings showing "as-build" conditions shall be furnished to the OWNER.

PART 3 -- EXECUTION

3.1 INSTALLATION

A. The CONTRACTOR shall employ installers who are skilled and experienced in the installation and connection of all elements, all instruments, all accessories, and all assemblies provided under this Contract.

B. The CONTRACTOR shall install all instruments according to the manufacturer's installation instructions and the following:

1. Perform field engineering as required for mounting and supporting all field mounted components.

2 Prepare any additional schematic and interconnection diagrams required for installation.

3. Assemble and interconnect instrument components disconnected for shipping purposes.

4. Remove all temporary supports, bracing, and padding inserted in instrument control panels and other equipment to prevent damage during shipping, storage, or installation.

5. All piping shall be field measured prior to fabrication and erection. Any significant discrepancies between drawings and field conditions shall be reported to the CONSTRUCTION MANAGER. The OWNER will not be responsible for any costs to

the CONTRACTOR for rework because of CONTRACTOR failure to take measurements prior to fabrication.

6. Adequately support and protect capillary tubing. All extra tubing shall be carefully coiled, tied, and protected at the instrument location.

C. The CONTRACTOR shall install pneumatic instrument air systems according to the manufacturer's installation instructions and the following:

1. Install all pneumatic tubing and make all connections at control panels, instruments, and control valves.

2. Perform field engineering as required for instrument air supply headers and individual air supply taps and lines.

3. Check all air supply branch headers by blowing with clean air and checking for tightness.

4. Clean all transmission and control tubing by blowing with dried and filtered air prior to connecting to instrument components.

5. Leak test all pneumatic control circuits in accordance with ISA Recommended Practice RP-7.1.

6. Set all instrument air regulators at manufacturer's recommended supply pressures.

D. It is the intent of the Contract Documents that all wiring external to Control Panels be provided under the requirements of Division 16. Further, it is the general intent that all 4-20 mA signal circuits, process equipment control wiring, signal wiring to field instruments, and Control Panel input and output wiring, be provided under Division 16 and be terminated and identified under Division 13.

E. The CONTRACTOR's attention is directed to the electrical and mechanical schematics and details of this project. Referral to these portions of the Contract Documents shall be required in order to understand the full intent and scope of work required.

F. Monitoring and control system configurations are diagrammatic only. Locations of equipment are approximate unless dimensioned on the drawings. Exact locations and routing of wiring and cables shall be governed by structural conditions, physical interferences, and locations of electrical terminations on equipment.

G. Where job conditions require minor changes in approximated locations and arrangements, the CONTRACTOR shall make such changes without additional cost to the OWNER.

H. All instruments shall be located and installed for ready access by the OWNER'S operation and maintenance staff. The OWNER reserves the right to require minor changes in location of equipment prior to roughing without any additional cost to the OWNER.

3.2 CONTROL PANEL SIGNAL AND CONTROL CIRCUIT WIRING

A. **Wiring Installation:** All wires shall be in plastic wireways except (1) field wiring, (2) wiring between mating blocks in adjacent sections, (3) wiring from components on a swing-out panel to components on the fixed structure, and (4) wiring to panel-mounted components. Wiring from components on a swing-out panel to other components on fixed panels shall be tied into bundles with nylon wire ties, and shall be secured to panels at both sides of the "hinge loop" so that conductors are not strained at the terminals.

B. Wiring to control devices on the front panels shall be tied together at short intervals with nylon wire ties and secured to the inside face of the panel using adhesive mounts.

C. Wiring to rear terminals on panel-mount instruments shall be in plastic wireways secured to horizontal brackets above or below the instruments in about the same plane as the rear of the instruments.

D. **Wire Marking:** Each signal, control, alarm, and indicating circuit conductor connected to a given electrical point shall be designated by a single unique number which shall be shown on all shop drawings. These numbers shall be marked on all conductors at every terminal using white numbered wire markers which shall be permanently marked heat-shrink plastic.

3.3 INSTRUMENT CABLE TESTS

N. **General:** The following tests shall be performed on each instrumentation and control system cable. All tests shall be end-to-end tests of installed cables with the ends supported in free air, not adjacent to any grounded object. All test data shall be recorded on forms which are available from the CONSTRUCTION MANAGER. Complete records of all tests shall be made and delivered to the CONSTRUCTION MANAGER. Each form shall be signed by the [CONSTRUCTION MANAGER or the CONSTRUCTION MANAGER's Representative] who witnessed the testing.

O. Continuity tests shall be performed by measuring wire/shield loop resistance of each signal cable as the wires, taken one at a time, are shorted to the channel shield. No loop resistance measurement shall vary by more than plus or minus 2 ohms from the calculated average loop resistance value.

P. Insulation resistance tests shall be performed by using a 500 volt megometer to measure the insulation resistance between each channel wire, between each channel wire and the channel shield, between individual channel shields in a multichannel cable, between each individual channel shield and the overall cable shield in a multi channel cable, between each wire and ground, and between each shield and ground. Values of resistance less than 1 megohms shall be unacceptable.

3.4 INSTALLATION, CALIBRATION, TESTING, PRECOMMISSIONING, STARTUP AND

INSTRUCTION

A. **Installation and Connection:** The CONTRACTOR shall install and connect all field-mounted components and assemblies under the following criteria:

1. Process sensing lines and air signal tubing shall be installed to the installation of conduit indicated under Section 16050. Individual tubes shall be run parallel and near the surfaces from which they are supported. Supports shall be used at intervals not longer than 3 feet of tubing.

2. Bends shall be formed with the proper tool and to uniform radii and shall be made without deforming or thinning the walls of the tubing. Plastic clips shall be used to hold individual plastic tubes parallel. Ends of tubing shall be square-cut and cleaned before insertion into fittings. Bulkhead fittings shall be provided at all panels requiring pipe or tubing entries.

3. All flexible cables and all capillary tubing shall be provided in flexible conduits. Lengths shall be sufficient to withdraw the cables and tubing for periodic maintenance.

4. Thermocouple lead wire shall be provided in dedicated conduit or wireway from the thermocouple to the control panel. Conduit or wireway shall be sized in accordance with the capacity of the instrument.

5. All power and all signal wires shall be terminated with spade type lugs.

6. All connectors shall be, as a minimum, water tight.

7. After all installation and connections have been completed, a technical field representative of the CONTRACTOR shall check the WORK for polarity of electric power and signal connections, leaks at all process connections, and conformance with requirements. The technical field representative shall certify in writing to the CONTRACTOR that each loop and system meets requirements.

8. All wire and all cable shall be connected from terminal to terminal without splices, arranged in a neat manner and securely supported in cable groups. All wiring shall be protected from sharp edges and corners.

B **Calibration:** All analog instrumentation and all control system equipment shall be calibrated and tested after installation to verify that requirements are satisfied. The CONTRACTOR shall provide all necessary labor, tools, and equipment to calibrate and test each instrument in accordance with the manufacturer's instructions. Each instrument shall be calibrated at a minimum of three points using test equipment to simulate inputs and read outputs. All test equipment and all instruments used to simulate inputs and read outputs shall be suitable for the purpose intended and shall have an accuracy better than the required accuracy of the instrument being calibrated. Test equipment shall have accuracies traceable to the NIST as applicable. All analog instruments shall be calibrated and tested in place without removal. Test data, applicable accuracy requirements, all instrument manufacturer published performance specifications and all

permissible tolerances at each point of calibration shall be entered on test forms available from the CONSTRUCTION MANAGER. These test forms shall verify compliance with all. A report shall be delivered to the CONSTRUCTION MANAGER for each instrument, certifying that the instrument has been calibrated in the presence of the [CONSTRUCTION MANAGER or the CONSTRUCTION MANAGER's designated representative] and meets contract and system requirements.

C. **Analog Loop Tests:** The CONTRACTOR shall be responsible for loop checking and testing all instrumentation loops with this project. The CONTRACTOR shall coordinate all loop check functions with the CSP to ensure that a single total loop check is conducted. The intent of the loop checks is to confirm and document each loop's component specification conformance up to and including all field-situated CSP devices. The CSP will have all control room personnel present to witness and confirm loop check results at the CRT level. The CONTRACTOR shall provide all necessary labor, tools, and equipment to field test, inspect and adjust each instrument to its indicated performance requirement in accordance with manufacturer's specifications and instructions. Any instrument which fails to meet any Contract requirement, or any published manufacturer performance specification for functional and operational parameters, whether or not indicated in the Contract Documents, shall be repaired or replaced, at the discretion of the CONSTRUCTION MANAGER at no additional cost to the OWNER.

1. At least [15] days before installation testing begins, the CONTRACTOR shall submit to the CONSTRUCTION MANAGER a detailed description, in duplicate, of the installation tests to be conducted to demonstrate correct installation of the instrumentation and control system and the anticipated dates the testing will occur.

2. Controllers and electronic function modules, shall be tested and exercised by the CONTRACTOR to demonstrate correct operation, first individually and then collectively as functional analog networks. Each hardwired analog control network shall be tested to verify proper performance within indicated accuracy tolerances. Accuracy tolerances for each analog network are defined as the root-mean-square-summation of individual component accuracy tolerances. Individual component accuracy tolerances shall be as indicated by contract requirements, or by published manufacturer accuracy specifications, whenever contract accuracy tolerances are not indicated.

3. Each analog network shall be tested by applying simulated inputs to the first element(s). Simulated sensor inputs corresponding to 10 percent, 50 percent, and 90 percent of span shall be applied, and the resulting outputs read to verify compliance to network accuracy tolerance requirements. Continuously variable analog inputs shall be applied to verify the proper operation of discrete devices. Temporary settings shall be made on controllers, alarms, etc., during analog loop tests. All analog loop test data shall be recorded on test forms, which include calculated root-mean-square-summation system accuracy tolerance requirements for each output.

4. Air systems shall be tested for leaks in compliance with ISA RP7.1.

5. When installation tests have been successfully completed for all individual instruments and all separate analog control networks, a certified copy of all test forms signed by the [CONSTRUCTION MANAGER or the CONSTRUCTION MANAGER's representative] as a witness, with test data entered, shall be submitted together with a clear and unequivocal statement that all instrumentation has been success fully calibrated, fully inspected, and fully tested.

D. **System Pre-commissioning:** The CONTRACTOR shall responsible for demonstrating the operability of all systems provided under this specification. The CSP will assist and coordinate the operability assessment with the CONTRACTOR. Pre-commissioning shall commence after acceptance of all wire, all calibrating and loop tests, and all inspections have been conducted. Pre-commissioning shall demonstrate proper operation of all systems with process equipment operating over full operating ranges under actual operating conditions.

1. The CONTRACTOR shall develop and submit to the CONSTRUCTION MANAGER for approval a Pre-Commissioning Plan which describes detailed test procedures, checklists, blank forms and data to be recorded, test equipment to be used and calculated tolerance limits.

2. System pre-commissioning activities shall include the use of water to establish service conditions that simulate, to the greatest extent possible, normal final control element operating conditions in terms of applied process loads, operating ranges and environmental conditions. Final control elements, control panels, and ancillary equipment shall be tested under start-up and steady-state operating conditions to verify that proper and stable control is achieved using motor control center and local field mounted control circuits. All hardwired and software control circuit interlocks and alarms shall be operational. The control of final control elements and ancillary equipment shall be tested using both manual and automatic (where provided) control circuits. The stable steady-state operation of final control elements running under the control of field mounted automatic analog controllers or software based controllers shall be assured by adjusting the controllers, as required, to eliminate oscillatory final control element operation. The transient stability of final control elements operating under the control of field mounted, and software based automatic analog controllers shall be verified by applying control signal disturbances, monitoring the amplitude and decay rate of control parameter oscillations (if any) and making necessary controller adjustments, as required, to eliminate excessive oscillatory amplitudes and decay rates.

3. All electronic control stations incorporating proportional, integral or differential control circuits shall be optimally tuned, experimentally, by applying control signal disturbances and adjusting the gain, reset or rate setting(s) as required to achieve a proper response. Measured final control element variable position/speed setpoint settings shall be compared to measured final control element position/speed values at 10 percent, 50 percent and 90 percent of span and the results checked against indicated accuracy tolerances. Accuracy tolerances are defined as the root-mean-square summation of individual component accuracy tolerances.

Individual component accuracy tolerances shall be as indicated in the Contract Documents or as specified by published manufacturer accuracy specifications whenever not indicated.

4. The CONTRACTOR shall submit an instrumentation and control system pre-commissioning completion report which shall state that all Contract requirements have been met and which shall include a listing of all instrumentation and all control system maintenance and repair activities conducted during the pre-commissioning testing. The CONSTRUCTION MANAGER must accept the instrumentation and control system pre-commissioning testing before the seven day operational testing may begin. Final acceptance of the control system shall coincide with final acceptance of the WORK.

E. **7-Day Operational Testing:** The CONTRACTOR shall furnish his own personnel, electrical personnel, and any instrument manufacturers representatives as required during the testing period required in Section 01660 to produce a fully operational system.

F. **Instruction:** The CONTRACTOR shall train the OWNER'S maintenance personnel in the maintenance, calibration and repair of all instruments provided under this contract.

1. The training shall be scheduled a minimum of 3 weeks in advance of the first session. The training shall be performed concurrent with the pre-commissioning in subparagraph D.

2. The training shall be performed by qualified representatives of the instrument manufacturers and shall be specific to each instrument model provided. Instructors shall have at least 2 years of training experience.

3. Each training class shall be a minimum of [8] hours in duration and shall cover Operational Theory, Maintenance, Trouble Shooting/Repair, and Calibration of the instrument.

4. Proposed training material, including resumes for the proposed instructors and a detailed outline of each lesson shall be submitted to the CONSTRUCTION MANAGER at least 30 days in advance of when the lesson is to be given. The CONSTRUCTION MANAGER shall review the submitted data for suitability and provide comments which shall be incorporated into the course.
5. Within 10 days after the completion of each lesson the CONTRACTOR shall present to the CONSTRUCTION MANAGER the following:

   a. A list of all OWNER personnel that attended the lesson.

   b. An evaluation of OWNER personnel knowledge through written testing or equivalent.

   c. A copy of text utilized during the lesson with all notes, diagrams, and comments.

3.5 PROCESS CONTROL STRATEGIES

A. The following control strategies complement the process control strategies on the Process and Instrumentation Diagrams. All materials and components shall be furnished, whether explicitly indicated or not, to effect the functional requirements defined on the P&IDs and in the process control strategy descriptions. The CONTRACTOR shall utilize the control strategies as a resource in generating control narratives to be included in the analog hardware submittal.

B. Common functions that are generally applicable to all strategies or to similar strategies are described under the heading "General Functions". These functions are not repeated in the descriptions for each strategy.

C. Each strategy is described as follows;

1. Overview: A brief description of the mission of the related strategy including the roles of logic, monitoring and control stations located/associated with MCCs, field situated, and , DCS -based.

2. Detailed Strategy Functions: A detailed description of each and every monitoring and control function associated with the associated strategy. This description addresses the strategies reaction to sensor failures, process equipment failures, control device failures, DCS malfunctions, and power interruptions. All control modes (MCC, local hand station, local control panel, DCS keyboard) are fully described. These descriptions are augmented by a listing of all instruments, valves, control devices, process equipment, and DCS equipment associated with the noted strategy. All control sequences associated with equipment activation, deactivation, process startup and process shutdown are defined along with all required time delays.

3. **Preface to Control Strategy Section:**

Tag numbering system
Definitions and terms
Controls and control functions provided for all equipment, unless otherwise noted
Local control station at equipment
Local/DCS switch
Alarms logic - open contact for alarms (fail-safe)

4. **Format for Each Strategy**

a. General Description

(1) An overall description of the process
(2) Major control components (PCM, PLC, annunciator, panels)
(3) General function of each major control component
(4) P & ID references for this strategy

(5) Reference to I/O listing

b. Related Equipment:

c. Overview of Strategy

d. Non-DCS Control

(1) Local Manual Control: Description of monitoring and control from each equipment item. If this is covered by the general statement in the Preface, describe any deviations. Example: "Because of inaccessibility location of this valve in the sump, a local control station is not provided."

(2) Remote Manual Control: Description of control from any local or area control panels. Other Control: Package system, PLC, etc.

e. DCS alarm, monitoring and control functions

(1) DCS Manual Control

(2) DCS Automatic Control

(3) Alarms - define alarms and alarm priorities. Define level (1, 2, 3, or 4) for each alarm

f. Failure Modes

g. Communications Interfaces

h. In-Service/Out of Service Algorithm: Description of devices which determine in/out of service status for each piece of equipment. (In-service (I/S)/out of service (OOS) algorithms mask or block out all or selected alarms associated with the OOS device i.e., if a wetwell is declared OSS, low level alarms shall be inhibited. Additionally, if a device has been designated OSS, all control routines shall declare the equipment as being unavailable for service.

3.6 INSTRUMENT SUMMARY

A. **General:** The Instrument Summary (IS) contained herein itemizes the instrumentation devices, including control panels, to be furnished under this contract.

B. Each column on the is defined as follows:

1. Tag Number: The identifier assigned to a device which performs a function in the control system. The CONTRACTOR shall use this identifier in tagging devices in the field.

2. Loop Number: The number assigned to the control loop associated with the device.

3. Description: A process-oriented functional description which defines the measured/monitored/controlled parameter and the associated process/process equipment.

4. P&ID Drawing Number: The Process and Instrumentation drawing upon which the device appears.

5. Technical Specification Number: The number associated with the technical specification which describes the requirements associated with the device.

6. Specification Section Number: The specification section under which the device shall be provided.

7. Control Panel Number: The designation of the control panel where the device resides.

8. Control Panel Reference Number: The drawing or schedule number associated with the control panel's face-plate representation.

9. Mechanical Drawing Number: The mechanical drawing upon which the device appears.

10. Electrical Drawing Number: The electrical drawing upon which the device appears.

11. Installation Detail Number: The designation of the installation detail defining the installation requirements associated with the device.

3.7 DCS INPUT/OUTPUT (I/O) SUMMARY

A. **General:** The I/O summary contained herein itemizes all inputs and outputs to and from the DCS which is furnished by the CSP.

B. Each column on the I/O summary is defined as follows:

1. Tag Number: The identifier assigned to a device which performs a function in the control system. The CSP shall use this identifier in tagging devices in the DCS.

2. Loop Number: The number assigned to the control loop associated with the I/O.

3. Description: A process-oriented functional description which defines the measured/monitored/controlled parameter and the associated process/process equipment.

4. P&ID Drawing Number: The Process and Instrumentation drawing upon which the device

appears.

5. I/O Classification: The type of I/O required for current and future monitoring and control activities (spare I/O is not included).

    a. Analog Input (AI): If the tag number generates an AI, the quantity of AIs are listed here.

    b. Analog Output (AO): If the tag number generates an AO, the quantity of AOs are listed here.

    c. Discrete Input (DI): If the tag number generates a DI, the quantity of Dis are listed here.

    d. Discrete Output (DO): If the tag number generates a DO, the quantity of DOs are listed here.

    e. Communication Link Identifier

    f. All future I/O is uniquely annotated.

6. PCM /PLC Number: The designation of the PCM where the I/O resides.

7. Remote I/O (RIO) Number: The designation of the RIO where the I/O resides.

8. Fail-safe: (Yes or No) : For digital inputs, whether the field device is to be wired as "open contact on alarm".

9. Remarks: Any clarifying remarks are made in this area such as pulse inputs, cross references to mechanical and electrical drawings on which the PCM appears.

10. Totals: A summary row which indicates the total amount of each type of I/O associated with a PCM. I/O associated with future shall be separately tabulated.

** END OF SECTION **

APPENDIX

TABLE 13300-1

MATRIX OF CONTRACT RESPONSIBILITIES
EQUIPMENT, DEVICES, AND MATERIALS

Products	Supply	Install
DCS Process Control Modules (PCMs)	CSP	ACC
DCS Workstations (WSs)	CSP	CSP
DCS Historian System (HS)	CSP	CSP
DCS PIN/FIN Hubs and network equipment	CSP	CSP
DCS Printers and Stands	CSP	CSP
Fiber Optic Network Cables (PIN and FIN cables)	CSP	CSP
Fiber Optic "DIN Cables"	CSP	ACC
All Other Communication Cables which Interconnect DCS	CSP	CSP
UPS Systems and Ancillaries for CSP provided equipment	CSP	ACC
Instrumentation Panels (including PLC's) and racks provided by	CSP	ACC
Panels (including PLCs) and racks provided by ACCs	ACC	ACC
Instrumentation provided by ACCs	ACC	ACC
Instrumentation provided by CSP (including specialized communications cables required.)	CSP	ACC
Interposing relays to interface DCS control commands with	ACC	ACC
DCS Isolated (Reference) Grounding Cables and Rods	ACC	ACC
Closed-Circuit Television (CCTV)	ACC	ACC
Page/Party Communications System	ACC	ACC
Security Card Access System	ACC	ACC
Large Screen Control Room Video System	CSP	ACC

TABLE 13300-2

MATRIX OF CONTRACTS RESPONSIBILITIES
WIRE, CONDUIT, AND TERMINATIONS

Description	Supply	Install	Terminate
Power conduits and wire to ACC furnished equipment and devices.	ACC	ACC	ACC
Power conduits and wire to CSP furnished equipment and devices.	ACC	ACC	ACC
Signal conduits from CSP or ACC furnished instruments to CSP or ACC furnished equipment and device.	ACC	ACC	---
Signal wire/cable from CSP or ACC furnished instruments to CSP or ACC furnished equipment and devices.	ACC	ACC	ACC
All conduits associated with the PIN, FIN, DIN and other communication links.	ACC	ACC	----
PIN and FIN fiber optic, unshielded twisted-pair and coaxial cables	CSP	CSP	CSP
Other communications cables from ACC-supplied equipment to the DCS	ACC	ACC	ACC
All cable associated with the DIN	CSP	ACC	CSP
All conduits associated with the fire alarm, CCTV, page party and security/card reader systems.	ACC	ACC	----
All signal wire/cable associated with the fire alarm, CCTV, page party, and security/card reader systems.	ACC	ACC	ACC
All power wire/cable associated with the fire alarm, CCTV, page party and security/card reader systems	ACC	ACC	ACC
Ground conduits and wire/cable from power panel to PCM or any other CSP furnished equipment.	ACC	ACC	ACC

TABLE 13300-3

MATRIX OF CONTRACTS RESPONSIBILITIES
TESTING AND SERVICES

Task	CSP	ACC
Prepare DCS hardware/installation submittals (PCM, WSs, HS, CM, UPS, fire alarm system, CCTV, page party and security/card reader systems).	X	
Prepare DCS software submittal.	X	
Provide SAMA functional diagrams	X	
Prepare annotated software listings of all ACC-furnished PLCs and other programmable equipment		X
Prepare instrument submittal		X
Calibrate instruments		X
Prepare ACC panel submittals.		X
Prepare loop drawings to support the termination of all DCS I/O and the installation of all instruments.		X
Perform operational readiness test (ORT) of DCS.	X	
Perform ORT test of ACC panels.		X
Perform loop tests.	X	X
Participate in plant startup.	X	X
Provide DCS information to support ACC development of loop drawings	X	